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REPORT

ON THE SANITARY CONDITION OF THE

SUDBURY AND COCHITUATE WATER SUPPLIES

OF THE CITY OF BOSTON

--- BY ---

DESMOND FITZGERALD

RESIDENT ENGINEER

BOSTON, MASS., MARCH 1, 1890.

Boston Water Works,

March 1st, 1890.

Robert Grant Esq.,

Chairman Boston Water Board,

Sir:-

In obedience to a request of your Board I submit herewith a report on the sanitary condition of the Sudbury and Cochituate water supplies. Accompanying the report are several books volumes containing the details of every case of pollution now existing, so far as known, on the Sudbury and Cochituate water sheds. The number of each case is given, the name of the owner and tenant, the nature of the drainage, a description of the premises and the water course into which the drainage empties.

The report has been divided as follows:-

1. Introduction.
2. Brief description of the works.
3. Topographical description of the water sheds with map.
4. Geological description and map.
5. Examination by drainage districts with set of plans and statistical tables.
6. Population.
7. Chemical discussion with tables and diagrams.
8. Bad taste in the water.

9. Shallow flowage improvements.

10. Pollution to aqueducts.

11. Filtration.

12. Biological laboratory.

13. Appendix of documents.

I desire to make acknowledgement to the Director of the United States Geological Survey, to the Commission in charge of the State Survey and to the State Board of Health for courtesies received and to Mr. Frederick Brooks C. E. for assistance in the preparation of this report.

Very truly yours,

Desmond FitzGerald

Resident Engineer &c.

INTRODUCTION.

Determined efforts have been made for a number of years past to abate well know nuisances existing at the sources of Boston's Water Supply, but with varying degrees of success. In 1874 a Medical Commission consisting of Drs. Charles W. Swan, Edward S. Wood and H. P. Bowditch, made a very valuable report upon the sanitary qualities of the Sudbury and some other river-waters. As far back as 1875 it became my duty to call the attention of the Cochituate Water Board to the necessity for adopting a vigorous policy to protect the purity of the water. In 1879 at their request I made a detailed report showing the number of cases of contamination, and proceedings were instituted against the offenders. Owing to the uncertain bearing of the law, a test case was arranged, Martin vs. Gleason, Augustus P. Martin being then Mayor of the City of Boston, and Luther Ellis Gleason the proprietor of a hotel in Natick discharging filth into Pegan brook, a feeder of Lake Cochituate. Although the city was defeated in some of the lower courts, the case was carried to the Supreme Court and won by a decision which showed clearly the right of the city to protect itself against pollution as far as the Cochituate water shed was concerned. In the meantime water supplies had been introduced into some of the towns on the water shed, which greatly increased the danger, because much filth was

easily carried off by the discharge of waste water, which the towns naturally allowed to drain into the brooks until some of them became veritable sewers. In 1885 after the favorable decision of the Supreme Court, a more elaborate report was made under my direction showing all the existing sources of contamination on both the Sudbury and Cochituate supplies. It included descriptions of the different towns with suggestions for the treatment of the sewage outside of the Boston water shed limits. That report with plans is now on file in your office.

This simple statement gives very little idea of the long and hotly waged warfare in the Courts and before the Legislature for ten years. At first people were very little interested in such matters, and it was not supposed even by those most vitally concerned that a remedy could be found. There has been during the past few years a great change in the public mind in regard to maintaining the purity of its water supply. Almost everyone is more or less informed on such questions and the laws have been modified. Changes brought about by time have also led to broader views of the management of water works, and they have brought in new problems not always easy of solution.

I attempt in the present report to give a more complete idea of the several sanitary questions connected with the supply than has been possible before. Within recent years, the biologist with rapid advances in his special department, has developed a most important addition to our stock of knowledge in regard to

the life existing in water and has even gone so far as to detect and classify pathogenic germs. Chemical and biological examinations, and knowledge of the physical surroundings of a water and of the standard of purity of natural water in its vicinity afford the means, if brought together, of determining with confidence its sanitary qualities.

It is a most ungracious task to point out all the imperfections of so good a water as that delivered to Boston. Still our standard can never be too high in such matters and it is only by a full and complete knowledge of all the facts that advance can be made. I should much prefer to show the other side of the question. To discuss pollution is apt to give a wrong impression, especially to those who are easily frightened ~~at the word pollution~~, and who forget that the air they breathe contains probably ~~much~~ more impurity than the water we are considering.

I expect to show, that the future condition of the water supply depends largely upon the line of action laid down at the present time; that in the course of a very few years, by persistently following wise plans not merely can a stop be put to the process of deterioration which is now found to be going on, but a positive improvement in quality can be made.

Whatever action is taken it will be impossible immediately to affect the quality of the water delivered to the citizens of Boston. It takes several years to modify materially so large a supply. This could be made apparent to those who have made no

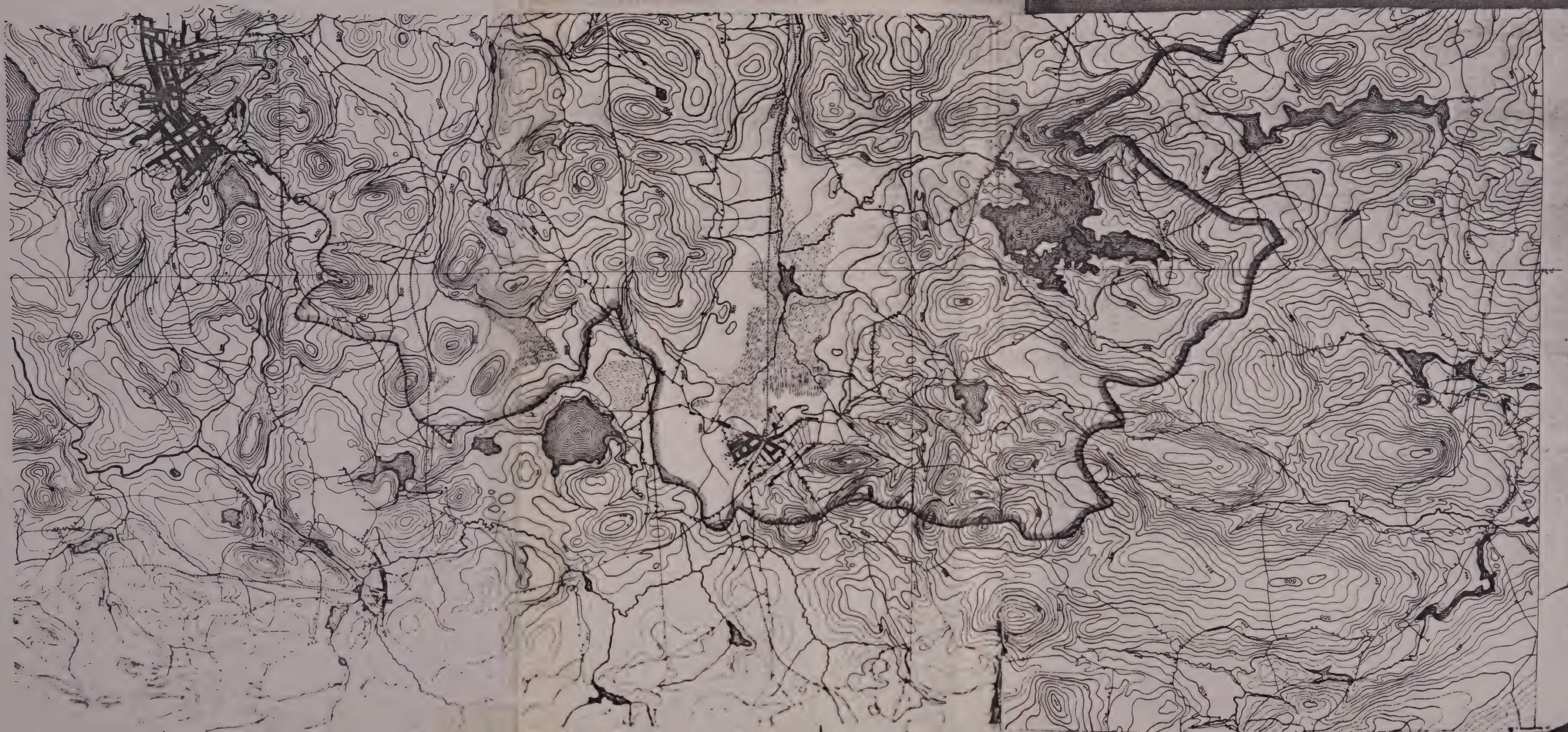
special study of the subject, if they would go to the sources of supply and follow out the various brooks, streams, lakes and reservoirs extending over nearly a hundred square miles included in the water shed. After driving about for several days, and then but imperfectly comprehending the relations of the different portions of the works under varying conditions of seasons and of rainfall, they would appreciate better the complexity of the work.

Map showing situation of the
SUDBURY & COCHITUATE WATERSHEDS

PLATE I.

Brief Description of the Works.

The Cochituate Lake supply was secured by Boston in 1848, and the Sudbury River in 1872. The former includes 18 sq. miles and the latter 75 sq. miles of water shed. Two aqueducts bring the water from these sources to the distributing reservoirs at Chestnut Hill and Brookline, where the two waters are mingled before being sent to the consumers. The accompanying map shows the situation of the ~~two~~ water sheds with reference to the city and to each other. The Cochituate water is collected in a single large lake about three and one-half miles in length, and the Sudbury water is stored in artificial basins formed by damming the streams. Four of these basins have already been constructed ~~and others are contemplated in the near future.~~ The Cochituate water shed is capable of yielding about twelve millions of gallons daily in years of extreme drought and the Sudbury about forty millions.



Topographical Description.

~~By the kindness of the authorities connected with the State survey I am enabled to present herewith a~~ The accompanying topographical map ~~which~~ taken from the State Survey gives an excellent idea of the Sudbury and Cochituate water sheds. Boston has acquired and paid for the right to all the water falling on the territory included within the colored lines, excepting such supply as may be necessary for the towns existing thereon. The green line surrounds the Cochituate drainage area, the brown the Sudbury, and the red line the isolated area draining into Farm Pond. The last can be connected with or shut off from the supply. The lakes, storage reservoirs, ponds and streams at present existing on these areas are represented in blue. By comparison with other maps in this report the names of all the places can be ascertained. This map shows the contours for every twenty feet in height.

It will be noticed at once that the Cochituate water shed is nearly flat; also that there are four principal brooks feeding Lake Cochituate, and that the surface of the Lake forms a very large proportion of its drainage area. There are considerable areas of marshy land upon the head waters of Beaver Dam Brook whose source is in the westerly part of the water shed near Waushakum pond. The shores of Lake Cochituate are of fine sand and the water coming from the great sand plain of Framingham and Natick is, in its natural condition, as good as any city could

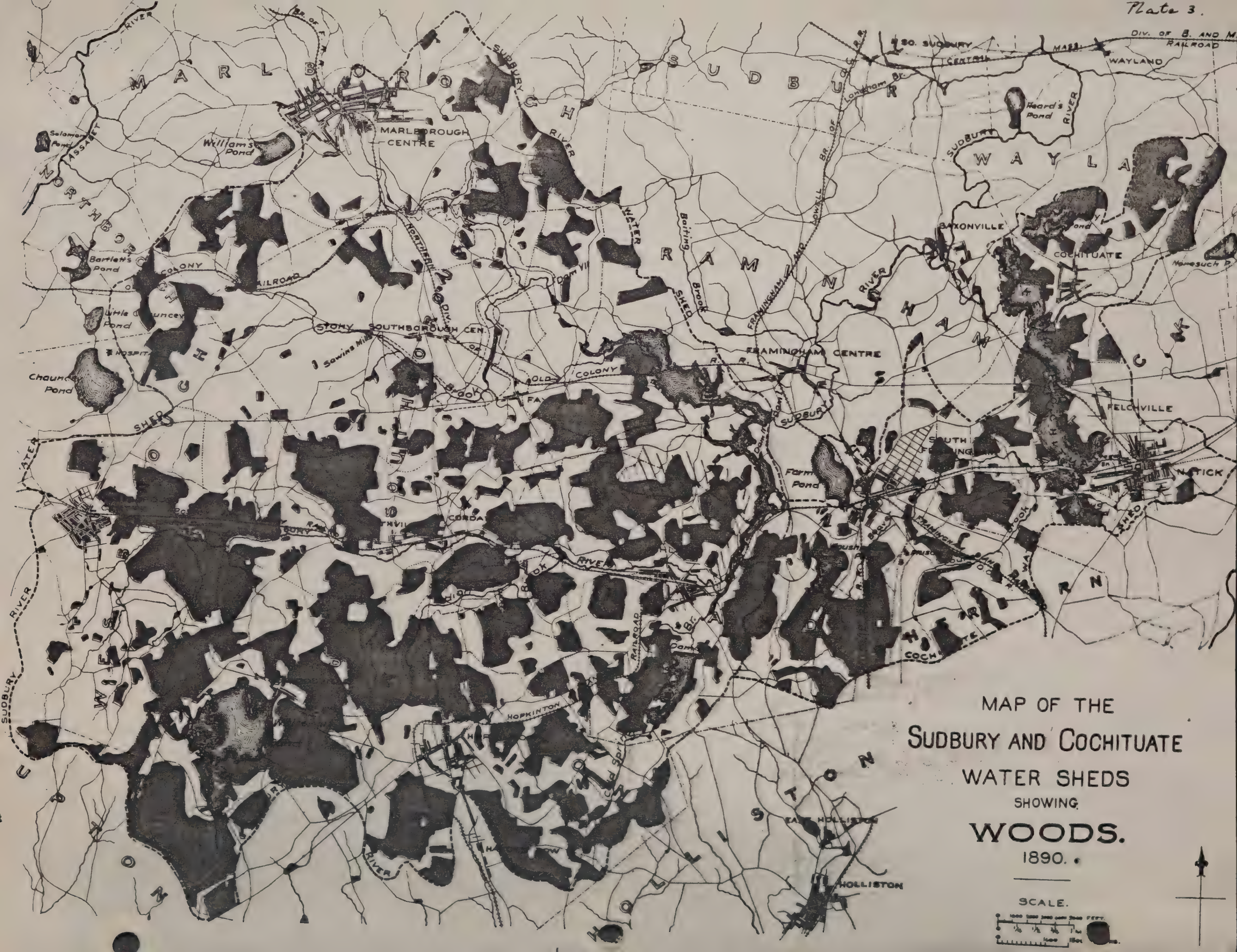
desire; nearly colorless, soft and remarkably agreeable to the taste. The two populous and rapidly growing villages of Natick and South Framingham at the eastern and western borders respectively of the drainage area, are, however, in dangerous proximity to the Lake.

The Sudbury water shed is generally hilly with few swampy or low places. All around its margin are high lands. These almost invariably yield a nearly colorless water. In the swamps of the valleys the water takes up a peaty color by prolonged contact with vegetation. Cedar Swamp is a marked topographical feature on the head waters of the Sudbury River. It is largely of artificial creation and is responsible for a considerable share of the high color of the water. Two principal streams unite to form the Sudbury River; to the southern, which rises near the village of Westborough, the name of Sudbury River is given; the northern, rising near the northern boundary of Westborough, is called Stony Brook. The contours show that the slopes on the Stony Brook area are steeper than on the main Sudbury; they are also more rocky, which gives a "quicker" water shed. Its water is naturally lighter in color and perhaps normally better than that of the main Sudbury, but on account of its greater contamination is now very inferior.

The scheme of development of the Sudbury supply by equalizing the flow, involves the building of numerous storage basins. At the junction of the two streams is Basin I. Immedi-

ately above it are Basin 2 on Sudbury River and Basin 3 on Stony Brook. Basin 4 is on Cold Spring Brook, a tributary of the Sudbury River entering just below the small village of Ashland. Above Ashland is another tributary, Indian Brook, on which Basin 6 is now building. Near the head waters of Indian Brook is a hill more than 500 ft. above the sea, upon the summit of which is the village of Hopkinton. Whitehall Brook, the outlet of Whitehall Pond, is another tributary of the main Sudbury at its upper waters in Cedar Swamp. Between Ashland and Cedar Swamp there are several mills on the river. The site of the projected Basin 7 on Stony Brook is mostly in Southborough but extends over the southern edge of Marlborough. Marlborough Village is shown among the hills at the northerly limit of the water shed.

Plate 3.



MAP OF THE
SUDBURY AND COCHITUATE
WATER SHEDS
SHOWING
WOODS.
1890.
SCALE.
MARLBOROUGH
MARLBOROUGH CENTRE
Williams Pond
Bartlett's Pond
Little Chauncey Pond
Chauncy Pond
NORTHBOROUGH
SOUTHBOROUGH
STONY
SOUTHBOROUGH CEN
FRAMINGHAM
FRAMINGHAM CENTRE
SOUTH FRAMINGHAM
Farm Pond
SAXONVILLE
COCHITUATE
FELCHVILLE
NATICK
WAYLAND
Heard's Pond
Nonesuch P.
SUDBURY
SO. SUDBURY
HOPKINTON
EAST HOLLISTON
HOLLISTON
WESTBOROUGH
CORDAVILLE
SUDBURY RIVER
ASSABET RIVER
OLD COLONY RAILROAD
NORTHERN DIV.
FRAMINGHAM AND LOWELL BR.
Br. of Lonham Br.
Div. of B. and M. Railroad
Cochituate Water Shed
Sudbury Water Shed

WOODS.

Thirty-three per cent of the Cochituate water shed is wooded and thirty-four per cent of the Sudbury. Separating the Sudbury area into two parts, but twenty per cent of the Stony Brook area is wooded, while forty-two per cent of the area draining into the main stream is covered with woods. The openness of the former, which is a farming country, contributes to the quickness of the flow from the steep slopes to such an extent, that in times of extreme freshet, the flow of Stony Brook is almost as great as that of Sudbury River with its larger area, its larger proportion of woodland and flatter slopes. While forests can in no way affect the quantity of the rainfall they certainly exercise an important influence by delaying the flow of water to the streams. Woodland indicates also the absence of human habitations and the probable normal condition of the water, and, except where existing in the form of swamps, is favorable to the purity of a water supply.

Particulars of the distribution of the woods ~~in the several districts are given~~ are shown in the accompanying ~~table.~~ map and table p. 14 ---


MAP OF THE
SUDBURY AND COCHITUATE
WATER SHEDS
1890.
SCALE.
MARLBOROUGH
NORTHBOROUGH
SUDBURY
WAYLAND
FRAMINGHAM
SAXONVILLE
FRAMINGHAM CENTRE
COCHITUATE
Nonesuch P.
HOLLISTON
EAST HOLLISTON
HAYDEN ROW
Williams Pond
Whitehall Pond
Heard's Pond
Chauncy Pond
Sudbury River
Boiling Brook
UPTON
ASHLAND
HOPKINTON
WOODVILLE
SAXONVILLE

GEOLOGICAL DESCRIPTION.

The geological character of a water-shed is of primary importance in determining the quality of the water. Through the kindness of the Director of the Geological Survey I am enabled to present the result of examinations made by that bureau in the Sudbury River water-shed. Prof. William O. Crosby of the Mass. Institute of Technology has supplemented this information by an examination of the Cochituate water-shed and he has also prepared the following description to accompany the map.

Geological description by Prof. W. O. Crosby

The water-sheds or drainage areas of the Upper Sudbury River and Lake Cochituate are essentially similar in their geological features, and since they are also coterminous, they may be conveniently embraced in the same general description. This is almost exclusively a region of ancient crystalline and metamorphic rocks, -granites, gneisses and schists predominating. The stratified rocks have been strongly folded and extensively eroded, dipping usually at high angles to the west or northwest; and they are, in general, clearly older than the eruptive rocks, -granite, diorite and trap.

Through Marlborough, the corner of Northborough, and the northern part of Westborough, hornblendic and micaceous schists with some slaty rocks and quartzites, are prominently developed with an approximately northeast and southwest strike. Farther south in Westborough mica schist and micaceous gneiss prevail, with a nearly north and south strike. In Southborough, gneiss, often reddish and largely of a granitoid character, mica schist and quartzite are the principal stratified rocks; and they extend southward into Hopkinton. The widely separated ledges protruding from the surface of the great sand-plain in Framingham indicate that the underlying rocks are chiefly gneiss and mica schist, which have originated in

the extreme alteration or metamorphism of beds of conglomerate and sandstone. These strata have been traced southward into Ashland and Sherborn; but they are in that direction much involved with granite. Granitic rocks, often indistinguishable from the granitoid gneisses, are found in all parts of the Sudbury basin, breaking irregularly through the stratified formations. But they occur most abundantly in Southborough, and especially southward in Hopkinton and Ashland; where they are usually of a pinkish color and somewhat micaceous, resembling the granite quarried at Braggville, in Milford. In the Cochituate basin the metamorphic slates and sandstones have been penetrated, chiefly along the bedding planes, by extensive intrusions of diorite, which is largely of a compact, greenish character; and at a later period both the sedimentary rocks and the diorite have been broken through in a highly irregular and intricate manner by numerous masses of granite, very commonly pinkish in color, like the Milford granite, but hornblendic instead of micaceous.

Throughout the region under consideration, rocks of a distinctly basic character, or such as are readily decomposed or dissolved, are very sparingly developed. Trap dikes, so abundant about Boston, are conspicuous by their absence in the Sudbury River basin. They have been observed, however, cutting through the diorite and granite in the eastern part of the Cochituate basin, and have been traced southwest from Weston across Natick and Sherborn to Holliston. There are

practically no calcareous rocks in these basins, the small deposit of limestone formerly exposed on the railroad near the south end of Lake Cochituate and described in Hitchcock's report on the Geology of the State being relatively quite insignificant. With unimportant exceptions, there are no iron-ores or distinctly ferruginous rocks in these formations; and no rocks containing more than the merest traces of sulphur, arsenic or other deleterious substances. In short, the hard rocks of this region are, so far as known, of a very stable and inert character and remarkably free from everything which could be regarded as prejudicial to the purity or wholesomeness of the waters flowing over or percolating through them.

The superficial formations - the drift deposits and soils which so generally encumber the surface and conceal the ledges are necessarily essentially similar chemically to the underlying rocks from which they have been derived; and they may be safely regarded as in the main equally devoid of every quality detrimental to the sanitary condition of the water supply. The importance of this point is sufficiently obvious on account of the intimate relations of the rain-fall to this permeable and almost universal mantle of detritus upon which it immediately descends. Under the general head of the drift deposits are included: (1) the till or boulder clay (unmodified drift), which rests directly upon the hard rocks; and (2) the overlying stratified sand and gravel (modified drift).

The true till is a stiff, tenacious and heterogeneous aggregate of clay, sand and stones of all sizes, which was formed under, and thoroughly pressed down and compacted by the great ice-sheeet. It is commonly known as <u>hard pan</u> and is not readily permeable by water. Although it forms a layer of irregular thickness covering the face of the country almost continuously, it has also been largely accumalated in the form of smoothly rounded hills, which are called <u>drumlins</u>. These are a prominent topographic feature of the region in question, being particularly well developed in Natick, Framingham and Marlborough They form in general the principal elevations of the district, being rarely exceeded in height by the rocky hills; and it thus happens that they form the water-parting between the Sudbury and adjoining basins at many points. The till undoubtedly tends through its impervious character, to arrest the downward progress of the water in the ground; hence rain-water falling on slopes of till, as on drumlins, must find its way to lower levels and into the streams and ponds by superficial seepage more generally than would otherwise be the case. In this respect the influence of the till is probably unfavorable to the purity of the water collected upon it.

On inspecting the maps showing the distribution of the drift deposits in this region it is apparent that, although the drumlins have their chief development in the Cochituate basin and the neighboring part of the Sudbury basin, the till as a whole, including what is not as well as what is in the form of

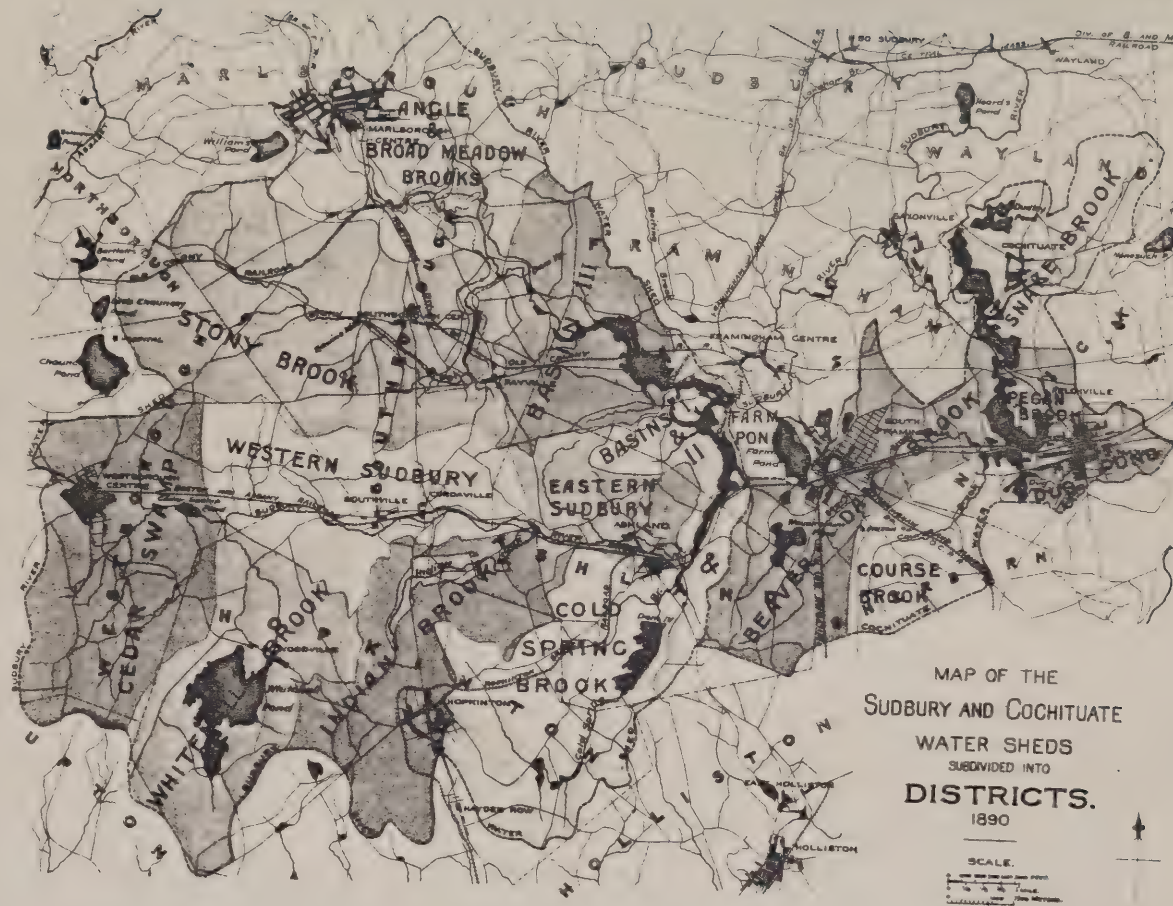
drumlins, is decidedly most abundant as a surface deposit in the central and western parts of the Sudbury basin. Hence it is in the reservoirs in the upper part of the Sudbury basin that the influence of the till upon the sanitary character of the water, due to surface drainage, should be most marked.

The modified drift includes not only the stratified sands and gravels, but also the clay beds, resulting from the washing over and assorting of large portions of the till by the floods of water which accompanied the melting of the great ice-sheet. The action of clay beds upon percolating waters would probably be similar to that of the till; but the clay washed from the till in the upper Sudbury and Cochituate basins must have been deposited chiefly far beyond their limits, and the remainder at such low levels within these basins as to have no appreciable influence upon the Boston water supply. The beds of sand and gravel, on the other hand, are very extensively developed in the form of level plains or plateaus and and also of hillocks and the long winding ridges known as Indian ridges or kames. Having been deposited in standing water, the temporary lakes which must have covered the land at the close of the ice age, they are necessaarily limited to the lower ground, forming the level floors of the valleys through which rise not only the ledgy hills, but also the drumlins or hills of unmodified drift. It is, doubtless, for this reason that, although found in all parts of the area under

consideration, these deposits have their most extensive and typical development in the Natick and Framingham district, forming the great plain which embraces the basins of Lake Cochituate and Farm Pond. These deposits consist chiefly of ~~quar~~ quartz sand and hard clean, water-worn pebbles; and this composition, together with their extremely porous and permeable character, must be very favorable to the purity of the water issuing from them. The rain-water passes at once and freely downward beyond the influence of the surface soil with its vegetable mould, until it reaches the surface of the till or of the hard rocks where the till is wanting. Although the modified is thus undoubtedly more favorable as a rule than the unmodified drift to the purity of the water supply, it is quite possible if not probable that this normal difference is neutralized in this instance by the fact that the level sand plains support a much ~~much~~ denser population than the till areas.

This region is, fortunately comparatively free from swampy tracts and peat bogs; but on the other hand, such as exist must rest chiefly upon the impervious boulder clay, which prevents the percolation and filtration of the swamp water.

OPP. P. 19


MAP OF THE
SUDBURY AND COCHITUATE
WATER SHEDS
SUBDIVIDED INTO
DISTRICTS.
1890
SCALE.
MARLBOROUGH
SUDBURY
WAYLAND
FRAMINGHAM
HOPKINTON
HOLLISTON
SOUTHBOROUGH
NORTHBOROUGH
ANGLE
BROAD MEADOW
BROOKS
STONY BROOK
WESTERN SUDBURY
EASTERN SUDBURY
BASINS
FARM
POND
COLD
SPRING
BROOK
INDIAN BROOK
WHITEHALL BROOK
CEDAR SWAMP
BEAVER DAM
COURSE
BROOK
PEGAN
BROOK
SNAKE BROOK
DUDLEY POND
FRAMINGHAM CENTRE
SOUTHVILLE
CORDAVILLE
ASHLAND
HOPKINTON
HOLLISTON
EAST HOLLISTON
WESTBOROUGH CENTRE
MARLBORO CENTRE
SAXONVILLE
COCHITUATE
Williams Pond
Chauncy Pond
Farm Pond
WAYLAND
SUDBURY RIVER
DIV. OF B. AND M. RAILROAD

Areas in square miles by towns & districts

	Districts —	Wayland	Natick	Sherborn	Framingham	Ashland	Holliston	Hopkinton	Upton	Southborough	Westborough	Northborough	Marlborough	Areas of Districts	Areas of Woods in Distr.	Percentage of District that is Wooded
	Lake Cochituate	·17	·75		·16									1·08		
I	Snake Brook	3·41	·59		·14									4·14	1·82	41
II	Pegan Brook		1·82											1·82	·48	26
III	Dug Pond		1·00											1·00	·19	19
IV	Course Brook		·75	2·71										3·46	·85	24
V	Beaver Dam Brook		1·74	·85	2·74	2·20								7·53	2·91	39
	Total Cochituate Watershed	3·58	6·65	3·56	3·04	2·20								19·03	6·25	33
VI	Farm Pond				·55									·55	0	0
VII	Bas. I & II & Cold Sprg B.				2·00	4·47	·03	5·32						11·82	4·31	36
VIII	Eastern Sudbury				·10	3·28								3·38	1·48	44
IX	Indian Brook					1·21		6·08						7·29	3·67	50
X	Western Sudbury					·69		1·51		2·70	2·56			7·46	3·07	41
XI	Whitehall Brook							7·23	·21		·10			7·54	4·36	58
XII	Cedar Swamp							·59	·35		8·36			9·30	2·73	28
XIII	Basin III				3·52	·30				2·17			·21	6·20	1·51	24
XIV	Stony Brook									9·34	1·71	·92	1·77	13·74	2·68	20
XV	Angle Brook									1·59			6·29	7·88	1·34	17
	Total Sudbury Watershed				5·62	9·95	·03	20·73	·56	15·80	12·73	·92	8·27	74·61	25·15	34
														Total Drainage Area	Area of Woods inside Water-sheds	Percentage of whole Area of Watersheds that is Wooded
	Town totals inside Watershed	3·58	6·65	3·56	9·21	12·15	·03	20·73	·56	15·80	12·73	·92	8·27	94·19	31·40	33
	Percentage that is wooded	43	30	23	19	50	0	52	75	18	29	32	24			

OPP P. 20

PLATE 7

SNAKE BROOK DISTRICT

including what drains into Snake Brook, Dudley Pond, and the northern part of Lake Cochituate

Examination by Districts.

For a more detailed examination of the water sheds they have been divided into fifteen districts following the natural drainage lines.

The Cochituate water shed contains five districts named Snake Brook District, Pegan Brook District, Dug Pond District, Course Brook District, and Beaver Dam Brook District. The water shed of Lake Cochituate is mostly included in the great sand plain mentioned in the geological description.

Snake Brook District.

Snake Brook District includes all the area which drains into the northerly or outlet end of Lake Cochituate, mostly by way of Snake Brook and Dudley Pond. The area, exclusive of water surface of the Lake, is 4.14 square miles, of which 3.41 are in Wayland, 0.59 in Natick and 0.14 in Framingham. Forty-one per cent. of the area is covered with woods. The population is 1900, of which 1700 are in Wayland, 175 in Natick and 25 in Framingham.

The district forms a part of the great sand plain of permeable material referred to in Prof. Crosby's report. The surface generally consists of a thin coating of loam under which are a few feet of sand underlaid often with clay. The district is comparatively free from serious cases of pollution, although

OPP. P. 22

PLATE 8

Plate 8, gives some details of the village of Cochituate, which is a portion of the town of Wayland. The situation is dangerously near to the aqueduct, Snake Brook and the Lake. Fortunately the sources of contamination are comparatively trifling but should the growth for any reason increase largely, ~~and there are indications of this tendency~~, it may be the source of trouble in the future. The industry of Cochituate is the manufacturing of boots and shoes. The principal firm engaged in business, W. & J. M. Bent & Co., employ about 500 hands. About 100 more are employed in half a dozen other shops. There are also about 200 employed in Felch's shop on the Natick side of Snake Brook.

The village is supplied with water, under the Wayland water act, from the head waters of Snake Brook. The population is 1700. There are 226 service pipes, 20 water closets, and all but a few houses are supplied. As water is used liberally, the consumption is probably about 70 000 gallons daily. Under a special provision of the Wayland water act, no sewer can be built in Cochituate. There is, however, surface drainage into Snake Brook

The red line in Plate 8, terminating in the letter A represents an open ditch, extending from Bent's factory at the corner of Lake Avenue and Main Street, and discharging upon the land of the city of Boston. The ditch has been used by the factory for the discharge of filthy water upon the city land. This nuisance has not been wholly remedied, and I recommend that the matter be followed up by proper legal measures to prevent the

opp. p. 24

PLATE 9

PECAN BROOK DISTRICT

including what drains into Bacon's Brook, Mc Ewan's Brook & south-eastern part of Lake Cochituate

&

DUG POND DISTRICT

Pegan Brook District.

The area of Pegan Brook District is 1.82 square miles, entirely within the town of Natick. Twenty-six per cent of this area is wooded The population is 5 600.

The principal industry carried on in the Pegan Brook District is boot and shoe manufacture. There are 15 shoe shops, employing about 1200 persons. There is a large baseball factory and some minor manufactures of lasts, inner soles, boxes &c, making a total population engaged in manufactures of nearly 1500.

The Pegan Brook District, as may be seen on the geological map, is of the modified drift, that is it consists of sands and gravels washed from the till formation, with the exception of the hills, which are of the till, or unmodified drift.

The district is drained by Pegan Brook, McEwan's Brook and other small tributaries entering the southeastern part of Lake Cochituate. The summer flow of Pegan Brook averages about 250 000 gallons daily. Just at its mouth are the Pegan Meadows extending over a considerable area and ~~flowed~~ covered with about six feet of water when the Lake is full. A few years ago the city built a dam in order to retain the water on these meadows at all seasons of the year, but the effect was not good and the dam was taken away two years ago. A highly contaminated brook like Pegan Brook, discharging into a shallow body of water creates an abnormal and offensive growth of algae. In 1886, 60 000 cubic yards of earth

were excavated from the shallow portions of the Pegan Meadows and the banks gravelled.

Pegan Brook with a water shed less than one half square mile in area, runs through the most thickly settled part of Natick, and discharges into the Lake a short distance below. This brook has become historical from the fact that its pollution has been the subject of much controversy and litigation. When the waters of the Lake were first taken, in 1846, this was a farming community, and there were certainly not more than two well authenticated places of pollution existing on the brook, one of which was the station of the Boston and Albany Railroad. As the town grew the waters of the brook were used more and more for the disposal of every kind of filth. This evil had grown to such an extent that in 1872, when I first became acquainted with the case, the brook was little better than a sewer; the water was nearly black and contained the refuse of a number of large factories including a hat factory which has since been abolished. So little, however, did this large amount of sewage affect the water delivered in the city, that at that time it was the general impression of experts that no trace of pollution could be found at the gate-house where the water passes into the aqueduct. ~~In~~ this connection, I give at some length the result of an examination made in 1873 by Prof. Wm Ripley Nichols for the State Board of Health, published in its fifth Annual Report. ×

× See 5th An. Rep. State Board of Health p. 113

without disturbing the rest of the dam. To provide for unusual flows of water, as in the case of spring freshets, a flume five feet in width, provided with stop-planks, was to be built through the dam." This plan was carried out originally as a temporary expedient, and a route, was surveyed for diverting the waters of the brook to Bannister's Brook, which empties into Sudbury River below the point where connection is made with Farm Pond. As this would reqiire the construction of an aqueduct two and a half miles long, and involve an expense of $70,000, it was felt that the work should not be undertaken except in the event of absolute necessity. The dam was rebuilt in 1867, and a second one, inside of the first, and some eighty feet distant, was built in 1870. The arrangement of these filter-dams may be seen on the accompanying plan, which is intended merely to give an idea of relative position, and is not drawn to scale.

Pegan Brook is joined by another brook in the meadow, but the waters of this brook are usually diverted into Dug Pond.

In this connection it may be further stated that outside of the filter-dams, at some distance from them, the waters of the arm of the lake, into which Pegan Brook enters, are in part cut off from the rest of the lake by a bar of gravel which extends from shore to shore, as indicated in the map on pagé 112, where also may be seen the relative position of the mouth of Pegan Brook (indicated by the letter C) with reference to the lake. There is through this gravel-bar a channel, the width of which varies with the height of the water; when the water of the lake is four feet below high water the channel is about thirty feet wide.

With regard to the efficiency of the means thus adopted for preventing the entrance into the lake of the offensive matters brought down into the settling-basins: At the time of a visit to the lake, made May 16, 1873, there was a considerable amount of water flowing in the brook; the presence of a large number of broken and useless household utensils along the banks, and the decaying carcass of a cat lying in the stream and making the air in the immediate vicinity offensive, showed that the brook was regarded as a natural receptacle for rubbish. The water in both the settling-basins was somewhat turbid and disagreeable to look upon. Outside of the outer embankment the water was somewhat clearer. At this time the water in the lake was at high-water mark, and the water inside the outer embankment was about two feet above the water of the lake. Samples of water taken at the flume inside the inner embankment and outside the outer embankment, showed that, as far as the dissolved impurities were concerned, no amelioration was effected. Subsequent examinations were made at various times during the latter part of the year. The results of the chemical examinations may be found in Tables V. and V a.

On the occasion of personal visits made on July 16 and 21, after a considerable period of dry weather, the stream was found to contain a rather small amount of clear and apparently inoffensive water. The hat-factory, the discharge from which on some occasions causes the water of the brook to be almost black, was not in operation at that time. The water in the first settling-basin contained a large amount of confervae, so as to be green and opaque in appearance; the second basin was of the same green color at the upper end; towards the lake it was turbid, but the turbidity was more of a clayey color. At this time the water in the lake was some three feet below high-water mark, and the whole of the outer face of the outer embankment was dry. The water within the embankment stood two feet or more higher than on the outside. From the southern end of the embankment issued a small, clear stream (d, p. 114), about equal in size to that which entered the upper basin, and, as appeared on chemical examination, even more impure, owing, no doubt, to the fact of its carrying off a portion of the matter which had previously collected in the basins. There is no doubt that the filterdams may and do arrest and retain a considerable amount of filth which would otherwise find its way into the lake. The filth retained, however, is matter which is insoluble, and the deposit has to be removed occasionally; the effect on the dissolved organic material is so extremely slight as to be of almost no account. This is, to be sure, what would be expected _a priori_, as filtration through a bed of gravel or sand saturated with water, and kept in such condition, could not be expected to remove the organic matter in solution.

It is to be observed that the examination made in December showed more satisfactory results, although in this case the character of the organic matter was very objectionable. At this time, also, the amount of dissolved oxygen was much greater than in the summer, as will be seen on the following page. It will be observed also that, at this time, the effect of the brook upon the water at the bar was greater than at the time of previous examinations.

The heights of the water in the lake at the time the samples were taken, were as follows, according to figures kindly furnished by Mr. D. Fitzgerald, Superintendent of the Western Division:-

	Above bottom of Aqueduct.	Below High-Water Mark.
May 12, ...	13ft. 4 in.	0
16, ...	13 1 1/2	0ft. 2 1/2 in.
July 1, ...	11 1 1/2	2 3
16, ...	10 2 1/2	3 1 1/2
Aug. 28, ...	8 8 1/2	4 7 1/2
Dec. 17, ...	9 4	4 0

On August 29, determinations were made on the spot of the amount of oxygen dissolved in the water, with the following results:-

	Oxygen. In cubic centimeters to the liter.	Oxygen. In cubic inches to the gallon.
Pegan Brook just before entering the first settling-basin, ...	1.91	0.44
First settling-basin, lower end, ...	1.06	0.24
Second settling-basin, upper end, ...	1.49	0.34
Second settling-basin, lower end, ...	1.66	0.38
Brook issuing from southern end (d, p. 114), ...	1.42	0.33
Brook issuing at centre (e,p.114), . .	1.31	0.30
Lake at outer bar, . .	3.78	0.87

On December 18 determinations were made of the amount of oxygen contained in the water of Pegan Brook, the stream issuing from the dam, and of the water in the lake. The waters were taken on December 17 at noon, and at that time were of a temperature not far from the freezing-point. The bottles in which they were taken were not opened until the succeeding morning. The oxygen was then determined, the waters being of the temperature in each case as indicated below:-

No.	Locality	Temp. in centigrade degrees.	Oxygen in cubic centimeters to liter.
204	Pegan Brook, ...	16°	7.8
203	Stream issuing from dam, .	16°	7.5
202	Lake, channel in bar, . .	16°	6.6

No.	Locality	Temp. in Fahrenheit degrees.	Oxygen in cubic inches to the gallon.
204	Pegan Brook, ...	61°	1.80
203	Stream issuing from dam, .	61°	1.73
202	Lake, channel in bar, . .	61°	1.52

This being the state of things with regard to Pegan Brook, the question immediately arises, Does the impurity thus entering the lake have any actual effect on the water, as regards its use for domestic purposes ? I think we are safe in believing that, at the present moment, there is nothing in the condition of the water, or in its effect upon the systems of those who drink it, which can be charged to Pegan Brook. A glance at the map, or at the lake itself, shows the enormous extent to which this impurity would be diluted, even supposing that it reached the consumer unchanged; but the progress of the water from this extreme end of the lake to the gate-house must be exceedingly slow, so that the opportunity for the chemical changes which affect the organic impurities of natural waters, when exposed to the light of the sun and to the oxygen of the air, is as favorable as it could well be. At any rate, the means of analysis at present at our command are insufficient to give us more than a slight suspicion of the presence of animal matter. On page 123 are collected together some of the previously published partial analyses of Cochituate water. As has been stated above, a general agreement will be observed in this respect, viz., that, as a rule, the relative proportion of organic matter has increased. My own examinations show, what is not unnatural, that the variations during the same season may be considerable, and my personal observation does not extend back through a sufficient number of years to lead me to assert that the water of the lake is less desirable for general use, than it has ever been before. As far as my observation does extend, the water, as received in Boston during the years 1872 and 1873, has been more strongly colored, and otherwise less pure than in the two years preceding. The color and the increase in the amount of organic substances, seems to be due to the presence of a larger quantity of vegetable matter. To fix absolutely upon the exact causes to which this change is to be attributed, is not possible. That the introduction of Sudbury River has contributed somewhat largely, there is no doubt; during the year 1872, the amount of water taken from the river was estimated at 1,676 million gallons, or about 110 days' supply; during the year 1873 no water has been taken from the river.

Another cause which probably is to be taken into the account is, that the water finding its way to the lake from that portion of its water-shed occupied by the town of Natick is probably less pure than formerly; moreover, during the years 1871-72 the water was very low, at one time even below the bottom of the conduit, and was pumped from the lake; this drain upon the lake and its water-shed probably contributed its share to bring about the general result, and it is possible that the influence of Pegan Brook was felt at the same time, not simply from its direct contributions, but from the drainage through the ground fouled by the material which is

deposited from it. In this immediate connection it may be instructive to compare together the results obtained at various times from the examination of the water at the bar, which partly shuts off from the lake the waters of the meadow into which Pegan Brook empties. (Compare Nos. 43, 79, 96, 202 in Table V. or V a.) At the time of the examination of No. 202 was made, the water in the lake was four feet below high-water mark, and, consequently, a considerable portion of the meadow was not covered with water. It is evident from the examination, that the influence of the material brought down by Pegan Brook was felt more at this time than previously, owing, no doubt, to the fact that the examination was made after a number of months of comparatively low water.

If, at the present time, the water of Cochituate Lake is well suited for all domestic uses, is there any well-grounded reason to fear for the future ? Decidedly there is. The town of Natick, as stated in the last report of the Board, feels the necessity of a water-supply. Whether this supply be taken from Charles River or from the lake, the natural outlet for any system of drains or sewers is to the lake. The introduction of water would, no doubt, soon and rapidly increase the proportion of filth brought down by Pegan Brook, and although the drainage of the more northern portion of the town would probably, for the present, be allowed to soak into the ground, and reach the lake only after an efficient purification, eventually, no doubt, it would find its way by actual drains. Moreover, at the present time, gas-works are being constructed in Natick, directly upon the brook, and the effect of these works will probably be to increase the amount of objectionable matter brought down into the settling-basins. How far this will affect the water of the lake remains to be seen. The discharge of gas-works into streams and ponds, in some instances, has been known to produce bad effects by killing the fish and by destroying the lower forms of animal life, which are important agents in preserving the purity of fresh water.

It is not necessary here to repeat what has already been said, as to the influence in general of sewage on the water of either streams or ponds into which it is allowed to flow; in the case of ponds or lakes, it is extremely important that no sewage-matter should be thrown into them. The changes to which such organic material is subject take place in the pond as in the river, and the destruction of the soluble organic matter is likely to be more complete if any does enter, especially if the water is drawn from the pond at a point distant from that at which it receives foul matters, so that, in a large pond, less immediate effect may be perceived than in the case of a river. The deposit of matter in suspension, which goes on continuously without the chance of removal by freshets, as in the case of rivers, is, however, preparing

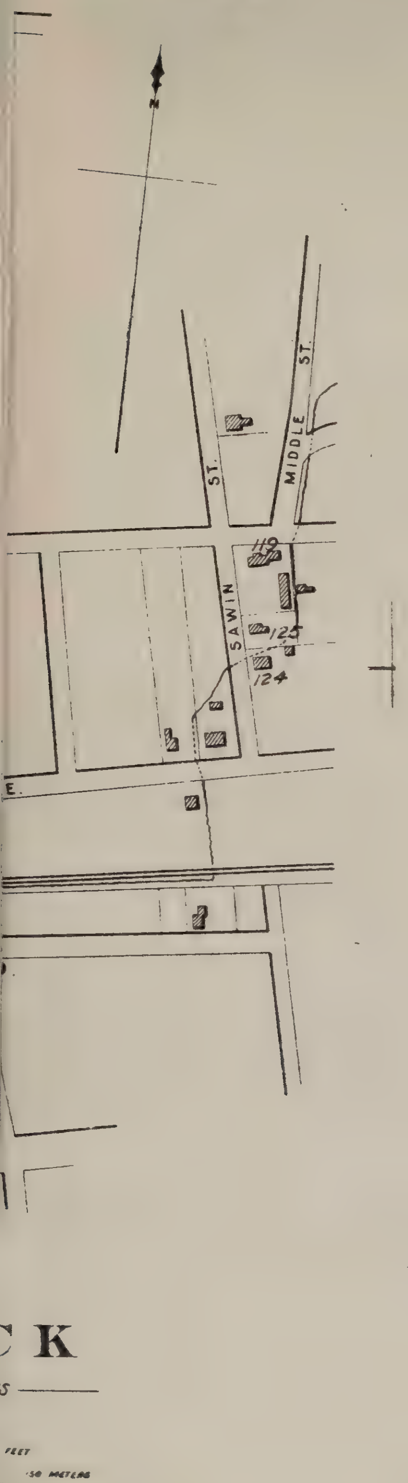
evil for the future. This deposit undergoes a slow process of decay, but increases continually, and is liable to be stirred up by heavy rains, especially after a dry time, when a portion of the deposit which forms at the point of discharge has been left uncovered by the water. The advantage of an intercepting lake, serving as a settling-basin, in the course of a polluted stream is great, and the water delivered from the lake in such a case is superior to that received; the efficiency, however, of such a agent of purification can be but limited, and a portion of its efficiency consists, no doubt, in the fact that it collects water coming from springs and draining from the surrounding country, and thus dilutes the impure with a purer water.

It is from a very strong feeling of danger of admitting sewage to any source of water-supply, that the hope is expressed that some measures will be devised for legally preventing such accessions. With the existing state of the law it seems impossible to obtain an injunction against such improper use of a water-course or of a pond, unless it can be shown, by actual proof, that the water is rendered unfit for use. It would thus be necessary quietly to observe the gradual deterroration of the water until actual sickness and death of water-takers made an injunction possible, and then the water would have been rendered almost hopelessly impure, and could hardly be brought back to its original state.

PLATE 10


NATICK
OLD DRAINS ARE SHOWN THUS
SCALE
FEET
METERS
NORTH MAIN ST.
BOSTON & ALBANY R.R.
WASHINGTON AVE.
BELLEVUE ST.
COCHITUATE ST.
HARRISON ST.
CHAMPNEY ST.
PEGAN BROOK
BACON'S BROOK
SUMMER ST.
SPRING ST.
MAIN ST.
COURT ST.
CENTRAL ST.
CLARENDON ST.
LINCOLN ST.
SOUTH AVE.
NORTH AVE.
WILLOW ST.
WALNUT ST.
WASHINGTON ST.
FRANKLIN ST.
HARVARD ST.
FLORENCE ST.
SAWIN ST.
MIDDLE ST.
HIGH ST.
ELM ST.
POND ST.

PLATE 10



opp. p. 34

Plate 11

Upper Brook below the gas house

marked improvement has taken place in the quality of the water of Pegan Brook. The citizens of this town, however, have endeavored by every possible device to baffle the work of the inspectors. Analyses show that several underground drains continue to pour water-closet, sink and other drainage into Pegan Brook. I regret to add that people in the middle of the night empty cesspools into the brooks rather than go to the small extra expense of removing their contents in a proper manner. ~~This~~ The condition of affairs and Natick illustrates the difficulty of securing a pure water supply from a thickly populated neighborhood, even with the law clearly on the side of protection.

Plate 10 shows the village of Natick in detail, and with every case of pollution marked in red. All these cases are described fully in the volumes accompanying this report.

Plate 11 is a photograph taken just below the gas house in Natick, to give an idea of the appearance of Pegan Brook. The difficulty of regulating a channel of this character passing through a town, will be at once recognized. The gas house which is represented in the photograph formerly drained directly into the water.

The determined action of the Boston Water Board in suppressing pollution [illegible]

An inspection of tables ~~10~~ X and ~~15~~ XV of the Chemical analyses shows that in the portion of Pegan Brook which is covered there are still a number of very bad cases of pollution. Of course, when a sewerage system is adopted by the town, these will be intercepted, and danger be obviated; but, until that time

comes, it seems advisable for the City to take action which will at once put a stop to what has no legal right to exist. Whether it is possible to seize the underground walls of this brook, or whether, under the decision of the Court, the City has the right to dig down and cut off these drains, it is important to determine. I believe a complete remedy will not be found until these drains are cut off.

The following extracts from Natick town reports give an idea of the feeling of the people on this subject;-

Extract from report for 1884.

The committee appointed by the town, and whose duty it is by vote of the town to defend the rights of Natick and its citizens against all suits pending, or that might be brought by the avaricious and aggressive policy of the city of Boston, in striving to prevent the town and its citizens from the exercise of their inalienable, natural and prescriptive rights and privileges, employed gentlemen of high legal attainments as counsel for the defence. The selectmen feel highly satisfied with the work of the committee, and can bear testimony to their ability and good judgment in carrying out their instructions with zeal and vigor.

Extract from report for 1882.

We would warn the people that unless decided steps are taken in the near future for getting rid of our sewage and drainage, we shall some day bitterly regret it. The need of some system of sewage increases each year, and sickness and death are certain to ensue unless some practical measure is soon devised for that purpose.

In the report of the Massachusetts Drainage Commission 1885, are the following remarks by Eliot C. Clarke, Engineer, on the subject of the Natick drainage,-

Natick would doubtless build a sewerage system if it could find some place at which to discharge the sewage. The feeling seems to be that as Boston, by acquiring a right to all

of the water within the Cochituate basin, has deprived the town of its natural outlet for drainage, the city ought in equity to be at the expense of providing another outlet. It may be said, however, that even if Lake Cochituate did not furnish a water supply, it would not be a suitable place in which to put sewage; since there is no current there, a nuisance would surely arise.

It seems evident to me that the water supply of Boston can never be considered safe until a comprehensive system of sewerage is adopted; and the people of Natick have, I think, been brought to see the necessity of this, for in the last town meeting a committee was appointed to consider and report upon the subject.

Dug Pond.

This district has an area of one square mile, entirely in Natick. Nineteen per cent of the area is wooded. The population is 1150. Consideration of the Dug Pond district might very well be omitted from this report, as its waters now supply the town of Natick, it having been seized by the town of Natick under an act of the Legislature. Dug Pond, however, is connected with Lake Cochituate by a culvert and overflow, which discharges water into the Lake when Natick has a surplus of water. Dug Pond is fed by a brook which runs through a thickly settled part of the town, and is called the south arm of Pegan Brook, but there are no cases of pollution on its course which compare with the ones on those branches of Pegan Brook discharging into Lake Cochituate. It is for the interest of Natick to protect this branch of the brook from contamination, in illustration of which the following extract is made from the town report for 1883, forcibly contrasting with the report already quoted about contamination of Boston's water supply.

Last July we inspected the south arm of Pegan Brook, from termination in Dug Pond to where it crosses the south Natick road. We found some sink drains emptying into the brook; one cesspool with a covered overflow into the brook; one privy within two feet of the brook; one pig-pen, the waste from which must go into the brook during high water; one barn cellar used as a receptacle for manure, and also as a privy vault, which is flooded by the brook during high water. These facts, with the names of the parties permitting the nuisances, were given in detail in a report made to us by the water commissioners. Since making said

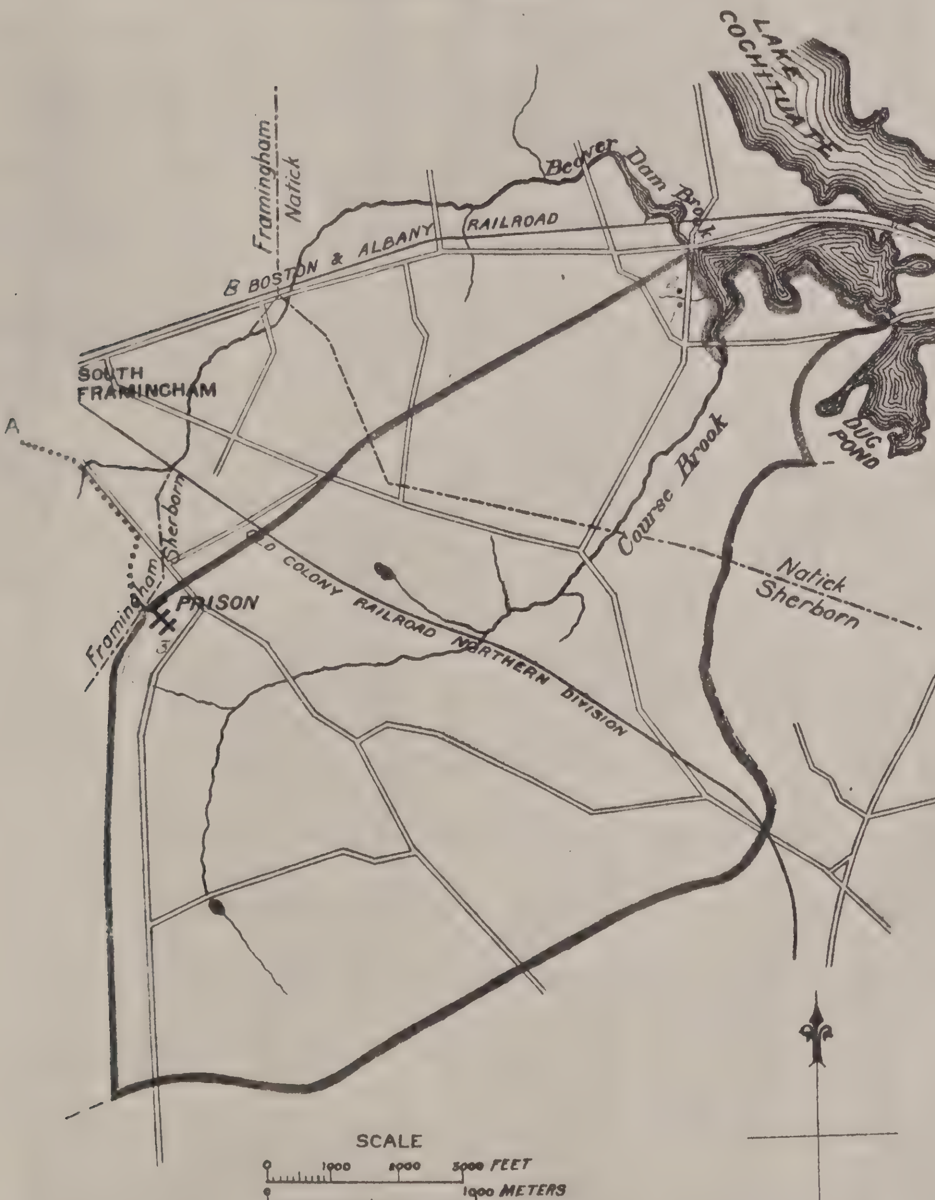
report we have learned that a sewer, connected with several dwelling houses, empties directly into the brook. The distance in a straight line from the mouth of this brook to the pumping station is 980 feet.

The direct pollution of our water supply from these sources of filth, must be evident to all. We see no other way to preserve the purity of our water supply, than by acquiring and maintaining permanent control of the brook and its banks.

PLATE 12

COURSE BROOK DISTRICT

including what drains into the south-western part of Lake Cochituate south of Beaver Dam Brook



Course Brook District.

Besides the drainage area of the brook the Course Brook District includes a very little of the margin of Lake Cochituate at its southwestern part south of Beaver Dam Brook. Its area is 3.46 square miles, of which 0.75 is in Natick, and 2.71 are in Sherborn. Twenty-four per cent of the whole area is wooded. The population is 560, 300 being in the Woman's Prison, 168 others in Sherborn and 92 in Natick. The Course Brook District is a farming region. The soil is gravelly. It is part of the great plain spoken of in the geological description with the exception of ~~3~~ three or four scattered drumlins.

Course Brook is one of the principal feeders of the Lake. It is remarkably free from any source of contamination, excepting the Sherborn prison, at its source. Foreseeing that the location of that institution would be a dangerous menace to the purity of the brook, a vigorous protest was entered against the adoption of the site, and soon after the building of the prison I called the attention of your Board to the necessity for proper disposal of its sewage. After a year or two of effort, a system of intermittent downward filtration was constructed under the direction of Col. George E. Waring, Jr. This system consisted in taking all the sewage of the building into two large flush tanks just outside, from which an intermittent discharge is carried on to the

filtration areas. After passing through three or four feet of soil, the effluent water ~~is~~ was discharged into the brook through a lower set of drains. An analysis of the effluent will be found in Table 10. Owing to the clayey nature of the soil the purification is not as perfect as it should be. This, of course, is a great improvement over the discharge of crude sewage into our water supply, but now that Since the construction of the sewerage system of South Framingham ~~is completed and~~ in operation, it is ~~to be hoped that the~~ drainage has been prison will ~~be~~ connected with it ~~, as it can be at an expense~~ & all danger from this source has passed. ~~comparatively trifling~~, amounting to $3600, according ~~to Mr. Clarke, page 191,~~ Mass. Drainage Commission's report, 1885.

Even with a properly designed filtration system there is danger that it may not be maintained with proper care, that parts may get out of working order and crude sewage find its way directly into a water course. This has actually occurred at the Sherborn prison, and the importance of insisting upon the discharge of the whole system into the Framingham sewer cannot be too strongly urged. On the plan are two red letters, A and B. These represent points for connecting with the Framingham sewers, A, that proposed by ~~Mr. Clarke~~ the Mass. Drainage Commission, and B, that suggested by the town authorities. The figures 1 and 2 refer to two cases of sink drainage.

The remainder of the Course Brook District is at present free from contamination and time can be taken for investigation of the question of purchasing strips of land along the borders of the brooks.

PLATE 13


BEAVER DAM BROOK DISTRICT
including what drains into Beaver Dam Brook and the south-western part of Lake Cochituate
SEWERAGE SYSTEM
SCALE
FEET
METERS
LEARNED'S POND
GLEASON'S POND
LOKERVILLE
FARM POND
SOUTH FRAMINGHAM
Beaver Dam Brook
Framingham
Natick
WAUSHAKUM POND
Prison
Framingham
Sherborn
Ashland
MILFORD BRANCH B.&A.R.R.
Ashland
Holliston
GRANT ST
FROST ST
BISHOP ST
SCALE
FEET
METERS
LOKERVILLE

Beaver Dam Brook District.

Besides the drainage area of the brook the Beavor Dam District includes a part of the southwestern margin of Lake Cochituate. The area is 7.53 square miles, of which 1.74 are in Natick, 0.85 in Sherborn, 2.74 in Framingham and 2.20 in Ashland. Thirty-nine per cent. of the district is wooded. The total population is 4530, of which 4000 are in Framingham, 222 in Sherborn, 163 in Natick and 145 in Ashland. The population is rapidly increasing at South Framingham, where, besides the Para Rubber Shoe Co., there are a large shoe shop, three rattan shops, a straw shop, the Gossamer Rubber Co., etc., within the Beaver Dam Brook District. The total number employed in manufactures is estimated at nearly 1500.

Beaver Dam Brook is the principal feeder of the Lake. There is quite a large area of marshy land at its head waters. After receiving the outflow from Waushakum Pond the brook flows ~~xxx~~ through the outskirts of South Framingham, is joined by several small brooks which drain that village, and, passing under the Boston and Albany Railroad near the Framingham and Natick boundary line, empties into the southerly division of Lake Cochituate.

The topographical and geological descriptions of the water sheds of the Sudbury and Cochituate areas mention a great sand plain which includes most of the Beaver Dam Brook District. This

PLATE 14


PART OF
SOUTH FRAMINGHAM.
SEWERS OF 1889 SYSTEM ARE SHOWN THUS
OLD DRAINS ARE SHOWN THUS
SCALE
400 FEET
150 METERS
SEWERAGE PUMPING STATION
CLARK ST.
CLINTON ST.
GRANT ST.
CONCORD ST.
MILTON ST.
FREEMAN ST.
BISHOP ST.
HILL ST.
BILLINGS STRAW SHOP
RUBBER SHOE CO
HOWARD ST.
BOSTON & ALBANY R.R.
WAVERLY ST.
MARBLE ST.
COOLIDGE ST.
OLD COLONY R.R.
BEAVER DAM BROOK
BEAVER
EASY ST.
ARLINGTON
IRVING ST.
PLEASANT ST.
Magnetic

OPP P. 42

PLATE 15

PART OF
SOUTH FRAMINGHAM

SEWERS OF 1889 SYSTEM ARE SHOWN THUS ----

SCALE

100 50 0 200 400 FEET

0 50 100 150 METERS

sand plain should furnish excellent water to the Lake, and has doubtless played an important part in producing the high degree of purity of the lake water. Previous to the year 1880 the water in Beaver Dam Brook was of excellent quality. A number of sewers were built in South Framingham in 1883, and in 1885 the Framingham Water Company began to supply water to the citizens. Soon afterwards the waters of Beaver Dam Brook began to show serious deterioration, and I have no doubt that the rise in the chlorine of the Lake since that time has been largely due to this source, perhaps even more than to Pegan Brook.

Plates 14 and 18 show different portions of the village of South Framingham; on the easterly side of the village and opposite to the pumping station [Plate 14] are a number of tenement and other houses which drain on to the surface of the ground in the vicinity of the brook. Following the brook towards its source, we come next to a ditch parallel with the Boston and Albany Railroad which receives the drainage from a district which is rapidly building up near the Para Rubber Works. A few years ago this was an open field through which trickled a small brook, dry in Summer. When the Para Rubber Shoe Company's factory was built a connection was made with this brook for the discharge of their sewage as shown on the plan. This still continues to run into the supply, and is one of the most serious sources of danger

(Nos. 47 to 60) into another branch in the neighborhood of Irving Street.

On Plate 13 the system of sewerage of South Framingham is shown in red, with the position of the pumping station and filter beds. The effluent is discharged into a small brook which empties into Sudbury River below the outlet of the Lake, so that no danger can arise from this source. This sewerage system has been recently completed, and towards its construction the City of Boston contributed the sum of $25,000.

The construction of the sewerage system in South Framingham is a matter upon which your Board should be congratulated, for, with a persistent inspection and proper supervision, the waters of the brook should return nearly to their former state of purity. As showing however that the construction of a sewerage system does not necessarily mean entire immunity from contamination, I will state that serious leaks have been recently discovered in the force main leading from the pumping station to the irrigation field, and that crude sewage was really being pumped for several days directly into Beaver Dam Brook. Efforts have been made by the town to stop these leaks, and with more or less success. This matter will be followed up until the force main is put into proper condition. I state this that a similar over-sight may be guarded against in the construction of other sewerage works on the Sudbury and Cochituate areas.

In connection with the sewer, under drains were built to lower the water table and to prevent leakage of ground water into the sewers, and since the completion of the system the contents of this under drain have been discharged into Beaver Dam Brook. Your Board have already entered into negotiations with the town of Framingham in regard to stopping the outlet of this under drain.

No matter if a system of sewerage for a town is carried out, there are always in the outlying areas a large number of small houses, and their drainage inevitably finds its way directly or indirectly into the stream. The builders of this class of houses generally select the lowest ground, and that which it is hardly ever designed to take into the sewerage system. The danger will always continue, unless strict sanitary regulations are carried out and enforced by the authorities of the town to prevent anything finding its way into the water courses. In the southerly part of South Framingham is an arm of Beaver Dam Brook which rises in a small pond by the side of the shoe shop of Bridges and Company. This brook together with the temporary connection which was constructed in 1872 for the purpose of deflecting the Sudbury River water into the Lake by means of Beaver Dam Brook, is shown on Plate 15. The latter ditch is built through a very low meadow, and receives some surface drainage from a group of houses near Farm Pond on Waverly Street.

It is important that the land on each side of Beaver Dam Brook and its tributaries should be secured; certain portions near to South Framingham, or within its limits, should be procured without delay.

PP. P. 47 - 4°

PLATE 76

PART OF SOUTH FRAMINGHAM

SEWERS OF 1889 SYSTEM ARE SHOWN THUS -----
OLD DRAINS ARE SHOWN THUS ———

Farm Pond District.

The Farm Pond District contains an area of 0.55 of a square mile, entirely in Framingham; exclusive of water surface the area is 0.27 of a square mile. It has no woods. The population is 1300. There is one manufacturing establishment, Barber's Straw Shop. This district is part of the great sand plain heretofore mentioned. As this district is not necessarily part of the Sudbury supply, a red line has been drawn on Plate 2 separating it from the Sudbury River and Cochituate areas. After the trouble with its waters in 1881, an aqueduct was constructed through the pond, connecting the waters from the basins of the Sudbury River system with the gate house of the Sudbury River aqueduct, so that water can be passed directly through the pond. This really throws Farm Pond district outside of our present supply, although by opening certain gates it can at any time be included. On the westerly shore of Farm Pond there was objectionable drainage coming from fertilized fields. A ditch was dug to intercept this drainage and to pass it into Sudbury River below the supply of the City of Boston, so that this leaves the small area on the easterly side of Farm Pond to contribute its water to the pond. The Framingham Water Company takes water from a filtering gallery on the easterly border of the pond, and pumps directly into the distribution pipes. The consumption of the water in South Fram-

ham is small, amounting ~~to~~ to about 160,000 gallons daily. The Para Rubber Company take a large share of their supply from Gleason's Pond, independent of the water supply company. The Boston and Albany Rail~~way~~ road pumps the water for the supply of ~~their~~ its locomotives directly from Farm Pond, having obtained the right before the city seized the water.

Plate 16 shows the portion of South Framingham which directly drains into Farm Pond. The Boston and Albany Railroad station is marked on this plan by the figure 14. Formerly this company drained directly into an arm of Barber's Brook, and so discharged into Farm Pond very near to the entrance of the Sudbury aqueduct, but this connection was cut off several years ago at my urgent solicitation. Entire safety can never be secured until this company connects its cesspools with the present sewerage system, which they are about to do. Barber's straw shop, represented by the figure 9, discharged a considerable quantity of black dye stuff into Barber's Brook, but this source of danger has been entirely removed. The row of tenement houses, marked 7, which drained formerly directly into Farm Pond, have since become connected with the sewer. While this drainage was passing into Farm Pond it was considered best not to use the water from the pond ~~directly~~ for the supply of the aqueduct, and it ~~has been~~ was shut off for more than a year, but after all the cases in South Framingham which pollute our supply are connected with the sewerage system,

the experiment will be tried of again turning the water of Sudbury River into the pond for the purpose of providing additional aeration.

PLATE 17

BASINS I & II & COLD SPRING BROOK DISTRICT

The Sudbury River Water Shed.

The Sudbury River watershed has been divided into nine districts, as will be seen on the index plan, viz. Basins 1 and 2 and Cold Spring Brook District, Eastern Sudbury District, Indian Brook District, Western Sudbury District, Whitehall Brook District, Cedar Swamp District, Basin 3 District, Stony Brook District, and Angle and Broad Meadow Brooks District.

A large portion of the Sudbury River watershed has impervious subsoil, contrasting with that of the Cochituate, which is pervious. A corresponding difference is found in the water of the two.

Basins 1 and 2 and Cold Spring Brook District.

Basins 1 and 2 and Cold Spring Brook District has an area of 11.82 square miles, of which 2.00 square miles are in Framingham, 4.47 in Ashland, 0.03 in Holliston, and 5.32 in Hopkinton. Thirty-six per cent. of this area is wooded. The population is 1370, of which 240 are in Framingham, 737 in Ashland, and 393 in Hopkinton. There are no considerable manufacturing establishments in the district. Geologically the lower portion is in the sand plain, the upper portion including Basin 4 is till, a mixture of clay, gravel, sand and stones. ~~As might be expected the upper end is very hilly.~~

In this large area are included three of the basins already

constructed, viz. Basins 1, 2 and 4, the latter being in Cold Spring Brook. This area is comparatively free from any sources of pollution. Cold Spring Brook is the best water supply that the city now has. The high color of Basin 4 water, particularly in the Autumn months, indicates the presence of swamps upon the feeders. As it is the only fault that can be found with the water, careful surveys should be made with reference to draining these swamps, and I think the result will show the desirability of securing land along the course of the brook above Basin 4.

From the outlet of Basin 4 to the Sudbury River is an area of low marshy ground through which the water that is drawn from Basin 4 has to pass and as in some portions it is lower than the outlet at the river, the water is kept stagnant in shallow pools which accumulate a considerable growth of algae and other forms of life. I have already pointed out to your Board the desirability of straightening, deepening and otherwise improving this channel. Surveys have been made and ~~some~~ the preparatory steps have been taken towards accomplishing this end. In connection with this work of improvement it will be extremely desirable to modify and improve the whole channel of the river from the culvert under the Boston and Albany Railroad at Ashland to the upper end of Basin 2. I should advise that, as soon as possible, a comprehensive plan be made for the treatment of this district, and when this plan is made it will be important to secure the land neces-

Plate 18

Basin 4, from upper end.

sary for carrying out the improvements indicated between Dam 4 and the upper end of Basin 2.

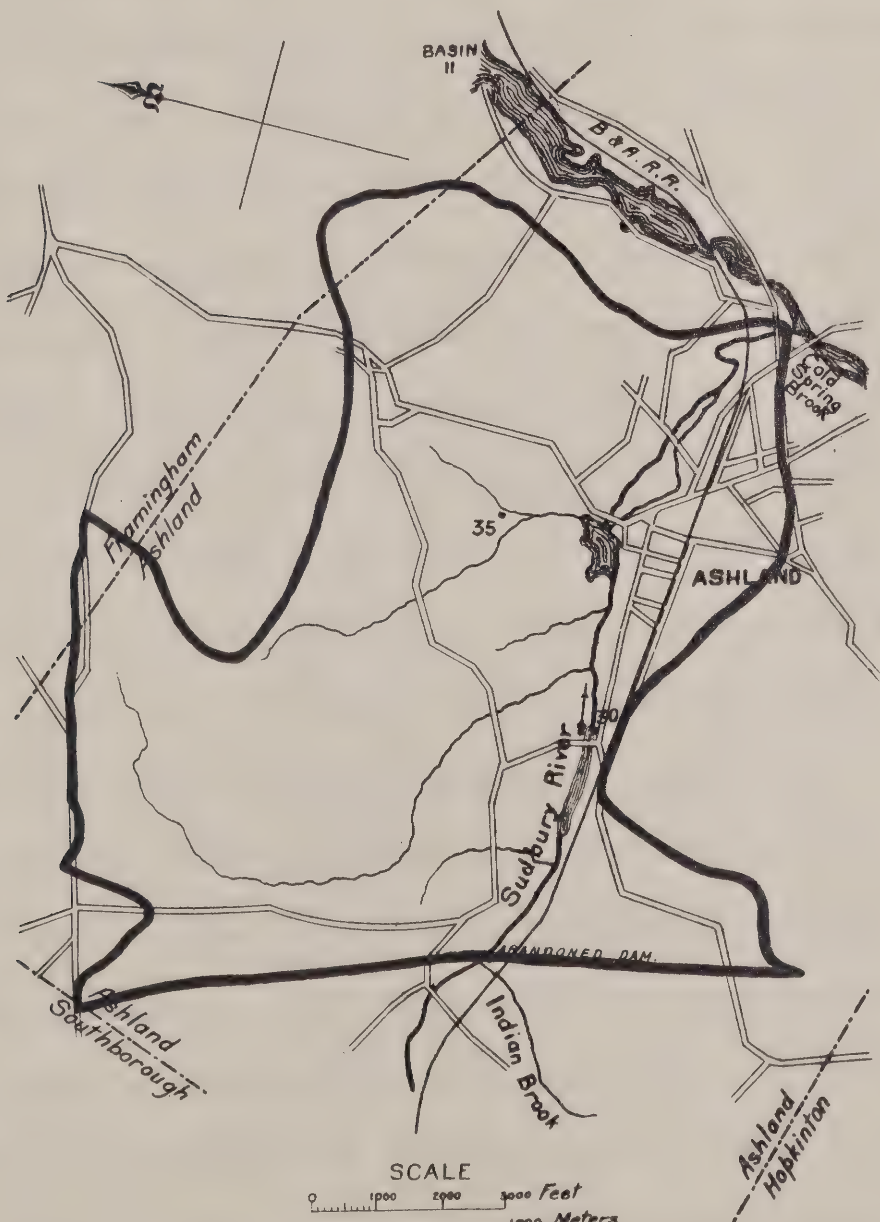
On Plate 17 four houses which are dangerously near to the Sudbury River at its junction with Cold Spring Brook, are indicated on a separate diagram to a larger scale.

Plate 18 is from a photograph taken ~~from~~ at the upper end of Basin 4, looking down stream towards the gatehouse. It gives an idea of the size of the basin, which is a mile long, and of ~~and~~ the surrounding country.

PLATE 19

EASTERN SUDBURY DISTRICT

including what drains into Sudbury River above Cold Spring Brook and below Indian Brook



Eastern Sudbury District.

The Eastern Sudbury District includes what drains into the Sudbury River above Cold Spring Brook and below Indian Brook. Its area is 3.38 square miles, of which 0.10 of a square mile is in the town of Framingham, and 3.28 square miles are in Ashland. Forty-four per cent. of the area is wooded. The population is 1720, or 512 per square mile, entirely in Ashland. There are about 600 people employed in manufactures, most of them in Tilton's shoe shop. The Warren Thread Co. employs about 60, and there are about 50 distributed among several small establishments. The district is mostly composed of till, and is very hilly except the village of Ashland, which is flat. In this district there are three dams on the river, first the Dwight Print Company's dam at Ashland, next, one at Metcalf's Box Factory (No. 30), and third an old, abandoned dam just below the mouth of Indian Brook. Future surveys will determine how much land it will be best to take on this portion of the river to control and improve its banks. The brooks outside the village in this district, drain an unsettled country, and it may not be necessary to take land on their borders for many years. Outside of the village of Ashland very little objectionable matter goes into the Sudbury River.

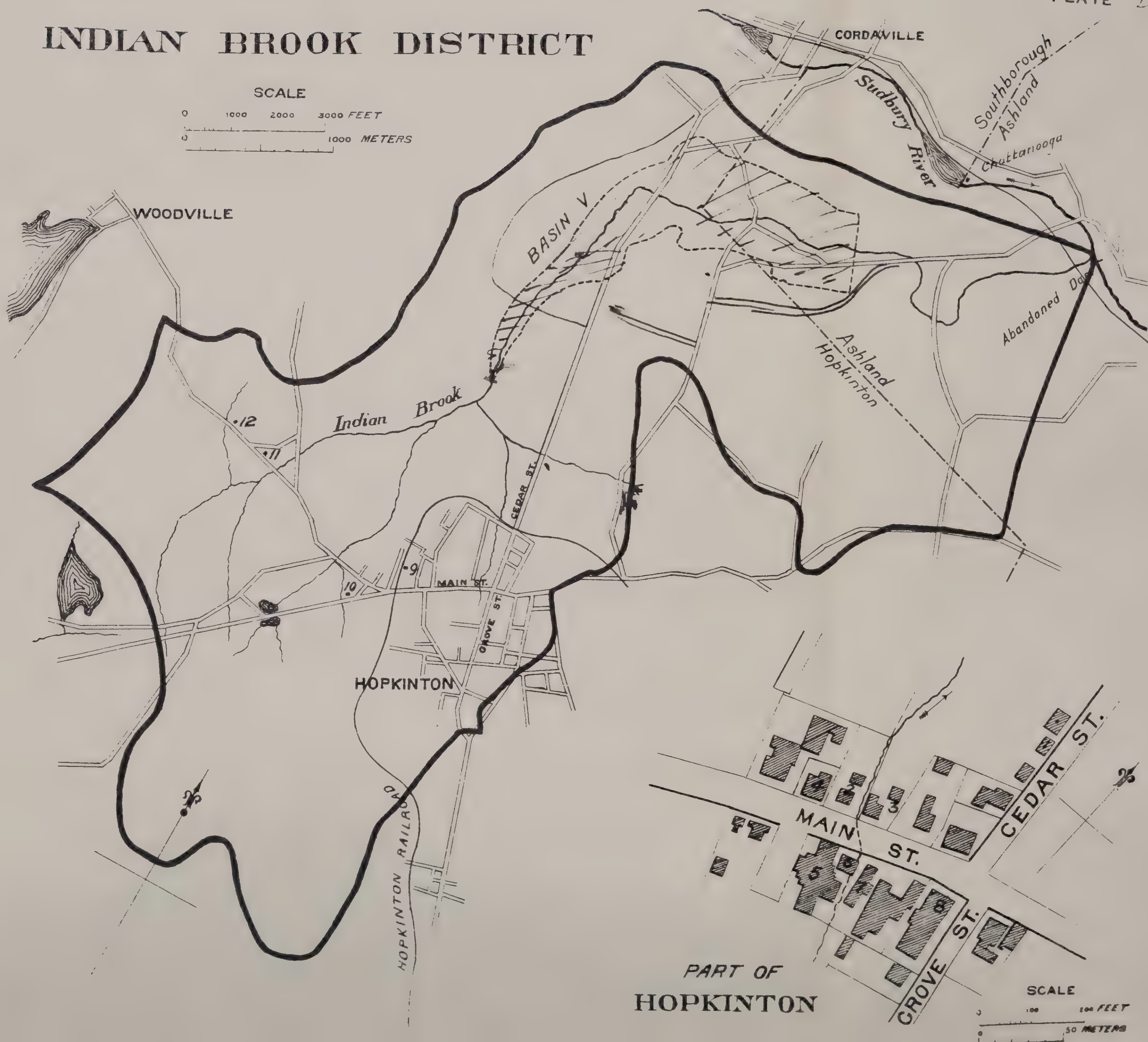
Passing now to an examination of the village of Ashland (Plate 20) we find that it is built on the banks of the river.

PLATE 2


ASHLAND
SCALE
100 50 0 200 400 FEET
0 50 100 150 METERS
SUDBURY RIVER
DWIGHT PRINT CO.
WARREN THREAD CO.
DWIGHT PRINT CO'S POND
TILTON'S SHOE SHOP
CEMETERY
BOSTON & ALBANY R.R.
HOPKINTON BRANCH R.R.
MAIN ST.
FRONT ST.
CONCORD ST.
GRANITE ST.
MYRTLE ST.
WATER ST.
PLEASANT ST.
TILTON AVE.
CHERRY ST.
HIGH ST.
ALDEN ST.
CENTRAL ST.
HOMER ST.
UNION ST.

There is but one brook flowing through the village as the plan shows. It passes near to Tilton's Shoe Shop (No. 16 on plan) but receives very little drainage on its way to the river. Two or three years ago there was a row of houses directly on the bank of the river, marked on the plan by figures 1 to 6. These were a disagreeable source of pollution, and as the amount of land was small and the expense trifling, the whole six buildings were purchased by the City, the houses moved away and the pollution stopped. The other cases in Ashland are comparatively small; ~~they~~ are described in detail in the books sent to your Board and they have already been or are fast being remedied. It is presumable that at some time in the future Ashland may require sewers. The following plan was suggested in the report of the Mass. Drainage Commission, p. 190.

> Whenever it shall be thought necessary to provide a sewerage system for Ashland, such system can find an outlet by the building of a main sewer to connect with the Framingham sewer. The distance will be about 12,000 feet, and surveys show that a practicable line for a sewer with fair inclination exists. In building a town sewer from the main sewer up Waverly Street in the direction of Ashland, this contingency should be borne in mind, and the sewer should be large enough to receive eventually the Ashland sewage. Probably a 15-inch pipe would be ample for the purpose.


INDIAN BROOK DISTRICT
SCALE
0 1000 2000 3000 FEET
0 1000 METERS
CORDAVILLE
Sudbury River
Southborough
Ashland
Chattanooga
WOODVILLE
BASIN V
Indian Brook
Ashland
Hopkinton
Abandoned Dam
•12
•11
CEDAR ST.
•9
10
MAIN ST.
GROVE ST.
HOPKINTON
HOPKINTON RAILROAD
MAIN ST.
CEDAR ST.
GROVE ST.
PART OF
HOPKINTON
SCALE
0 100 200 FEET
0 50 METERS

Indian Brook District.

Indian Brook District has an area of 7.29 square miles, 1.21 miles being in Ashland and 6.08 miles in Hopkinton. Fifty per cent of the area is wooded. The population is 2120, of which 66 are in Ashland and 2054 in Hopkinton. The population per square mile is 291.

On the head waters of Indian Brook, in the valley, is a very large area of swampy and marshy ground, which accounts for the high color of the Indian Brook water. I cannot say at present how much land it would be best to secure along the course of Indian Brook above the basin, to protect the supply for the future. Farther surveys are required. The rest of the district is very hilly; the hills are clayey and covered with bowlders so that the water runs quickly off the surface.

The district is generally free from pollution. The population is mostly concentrated in the village of Hopkinton, whose position with relation to the head waters of the brook, is shown on the plan. Fortunately for the City, Hopkinton, during the last ten or fifteen years, has not increased in population. Some of the industries formerly in the town, have been removed. The leading industry is the manufacture of boots and shoes, which employs a thousand people in the village in three large establishments. A separate plan has been made of a small part of the middle of the village. The topographical map

gives an idea of its situation on the hill. At present there is no material pollution from Hopkinton finding its way into Boston's supply, but the position of the town on so high and rocky a hill covered with an impervious material and where the surface drainage must be so quickly transferred, is at least threatening. The people are supplied with water from a public source by means of some six inch driven wells in the village. The consumption is about 40,000 gallons per day. As the source of Hopkinton's water supply is within its thickly settled portion, the drainage of the town is far more dangerous to its inhabitants than it is to the waters of Indian Brook, and chemical analyses will I think, corroborate this statement.

The sewage of Hopkinton can be very easily taken care of by some such method as that proposed by Mr. Clarke in the Massachusetts Drainage Commission Report, Plate 23. The expense would be small, and before pollution begins to manifest itself in any serious way the system had better be built. But there is less necessity for immediate action here than in some other places on the water shed.

On Indian Brook Basin 5 is now building. This is to be one of the most important supplies for the City. In area of water shed and in situation, it is almost an exact counterpart of Basin 4, yielding about the same quantity of water and having about the same storage capacity.

WESTERN SUDBURY DISTRICT
including what drains into the Sudbury River above Indian Brook and below Whitehall Brook

Western Sudbury District.

The Western Sudbury District includes what drains into Sudbury River above Indian Brook and below Whitehall Brook. This ~~includes~~ embraces that portion of the river extending from Ashland to Westborough. The area of the district is 7.46 square miles, of which 0.69 of a square mile is in Ashland, 1.51 in Hopkinton, 2.70 in Southborough, and 2.56 in Westborough. Forty-one per cent of the area is wooded. The population is 1140, of which 75 are in Ashland, 65 in Hopkinton, 900 in Southborough and 100 in Westborough; the rate of population is 153 per square mile. Geologically this is a region of till except the valley of the Sudbury River, which is filled with gravel washings from the great glacial epoch.

The river is quite a rapid stream in this district, and contains a large number of mill dams. Passing up the river the first dam is at a place called Chattanooga, ~~or~~ the site of Aldrich's Mill, where about 80 people ~~are~~ were formerly employed. ~~Formerly the privies~~ from this mill drained directly into the river, but they have been taken out. At present the only polluting matter which comes from this establishment is manufacturing refuse, and it is not very large in amount. The owner of these premises expresses a wish to keep them in good condition. In this connection it may be stated that the owners of two or three mills which exist along

[illegible]

the course of the Sudbury claim a prescriptive right to turn manufacturing refuse into the stream. They show a disposition to aid the city in keeping this matter out of the stream if it can be done without unnecessary expense to themselves.

The next mill on the river is that of the Cordaville Woolen Company at Cordaville, employing from twenty-five to one hundred hands. It is a manufactory of woolen blankets. Waste from the dye-house and washings are discharged into the stream. The privies of this establishment are located directly over the raceway and they formerly discharged directly into the water; they now have a removable box, whose contents are disposed of upon the ground away from the river. The location of the privies ought to be changed and the dyestuffs ought to be discharged into a cesspool, from which the contents can be removed. I think this can be brought about by paying the expense. There is no other pollution of the stream at Cordaville. The village contains about 200 people.

The next village on the stream, Southville, contains a population of 250. The only dam at this point is one recently acquired by the City, and there is no pollution from a manufacturing source. There are, however, a number of cases of superficial drainage, as shown in the diagram on Plate 22, consisting of house drainage passing into two brooks, which flow through the

village. The drainage is comparatively small in amount, however, and is under inspection and treatment.

There is no public water supply in this district. In a project for supplying the town of Southborough, which was submitted during the past winter, there was included an estimate for an extension of the supply to the villages of Southville and Cordaville.

The next mill on the river is that known as Rocklawn Mills at the outlet of Cedar Swamp. The dam backs the water into Cedar Swamp Pond, and if Cedar Swamp shall ever be drained as is proposed, the present dam will necessarily become the property of the City of Boston.

As the plan shows, there are in this district a number of small brooks whose banks are occupied as in the villages of Cordaville and Southville. They are liable to bring objectionable matter to the river and I think land should be secured on the borders of these streams without delay. Perhaps in the future it will be found best to seize a strip on each side of the main river in this district, but I am inclined to think that no sufficient gain would accrue to the water to justify the expenditure of a large sum of money for this purpose. A more accurate survey will determine what is expedient.

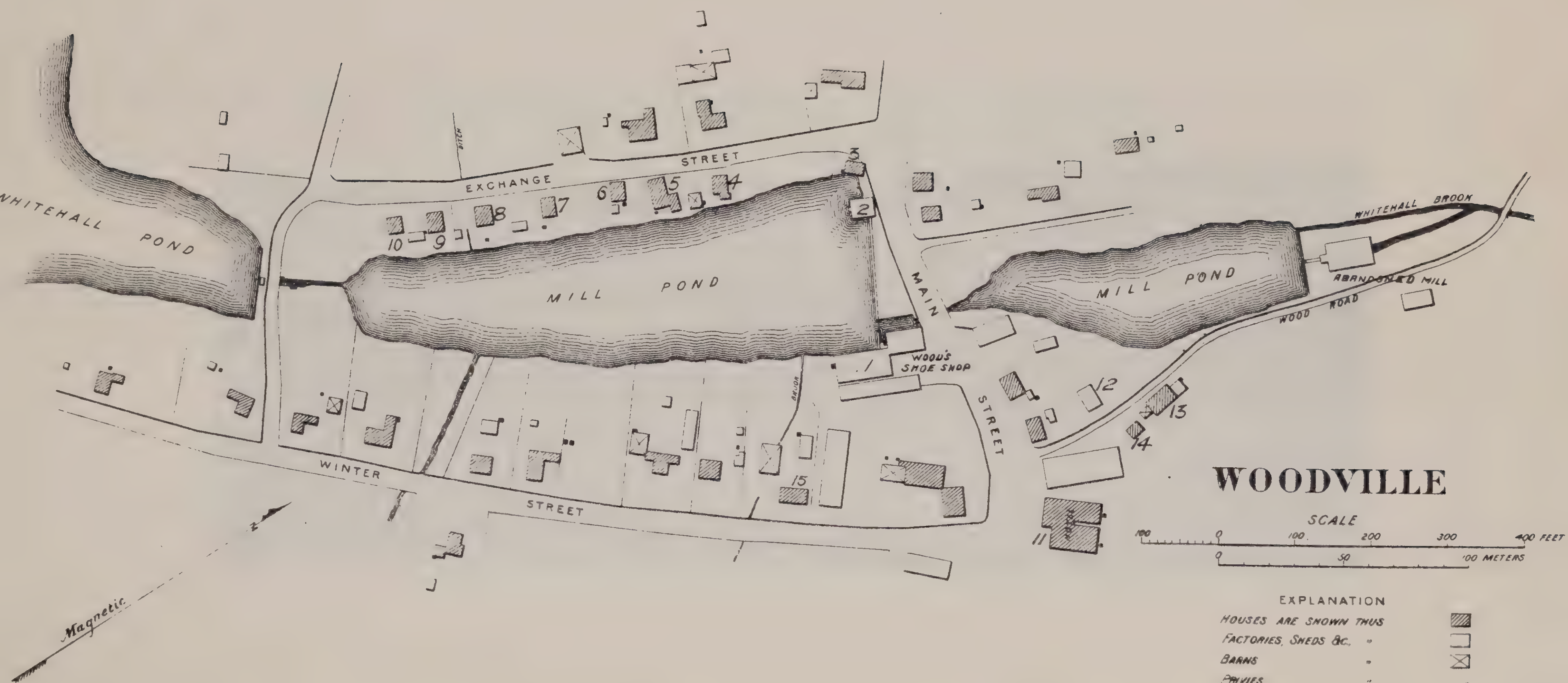

SCALE
0 1000 2000 3000 Feet
0 1000 Meters
Sudbury River
Westborough
Upton
Hopkinton
WHITEHALL POND
Dam
Dam
Dam
WOODVILLE
HOPKINTON R.R.
HOPKINTON

Whitehall Brook District.

The area of this district is 7.54 square miles, of which 7.23 are in the town of Hopkinton, 0.21 in Upton and 0.10 in Westborough. Fifty-eight per cent. of the area is wooded. This district contains the largest proportion of forest growth of any district on the whole Sudbury supply, and is, therefore, a favorable one for the water of the City of Boston. The population is 680, of which 674 are in Hopkinton and six in Westborough, making the rate 104 to the square mile. Four hundred and fifty are in the village of Woodville, where there is the one manufacturing establishment of the district, Wood's Shoe Shop, employing about 90 operatives. The district is surrounded by high rocky hills and is drained by Whitehall Brook, which is the outlet of Whitehall Pond. The only other body of water is the district is a small swamp. Whitehall Pond has a area of 600 acres. At its outlet are three dams, as shown on the plan, and clustered around these dams is the village of Woodville. Whitehall Pond was once owned by the City, and used as a compensating reservoir in connection with the owners of the Sudbury meadows below Lake Cochituate. The pond was sold by the City in 1854.

On the steep bank of the mill pond just below the outlet of Whitehall Pond there are a number of houses. Plate 27 shows photographically the west bank as seen from these houses, and

PLATE 24


WOODVILLE
SCALE
100 0 100 200 300 400 FEET
0 50 100 METERS
EXPLANATION
HOUSES ARE SHOWN THUS
FACTORIES, SHEDS &c. "
BARNS "
PRIVIES "
WHITEHALL POND
MILL POND
MILL POND
EXCHANGE STREET
WINTER STREET
MAIN STREET
WOOD ROAD
ABANDONED MILL
WHITEHALL BROOK
WOOD'S SHOE SHOP
DITCH
DRAIN
Magnetic
N
1
2
3
4
5
6
7
8
9
10
11
12
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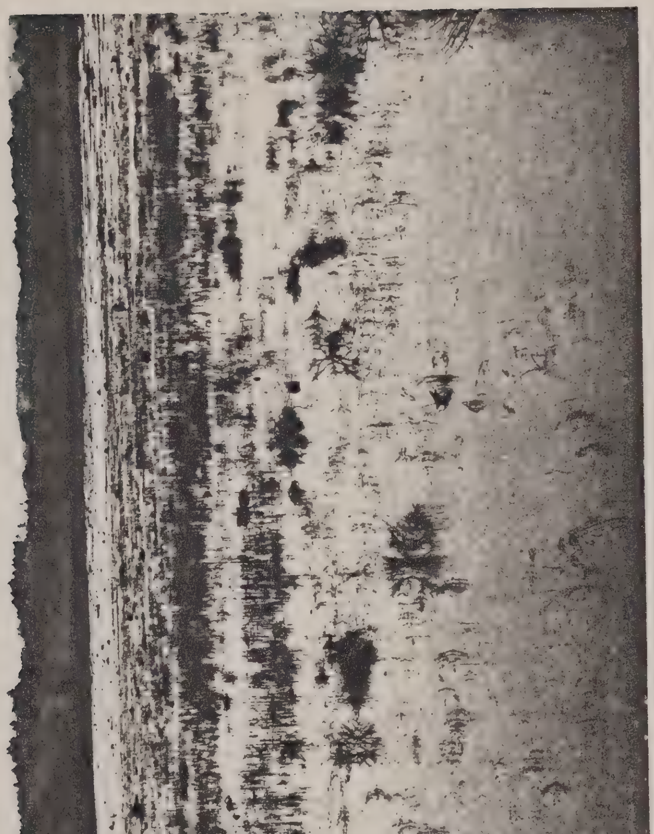
14
15

opp. p. 61

Plate 26

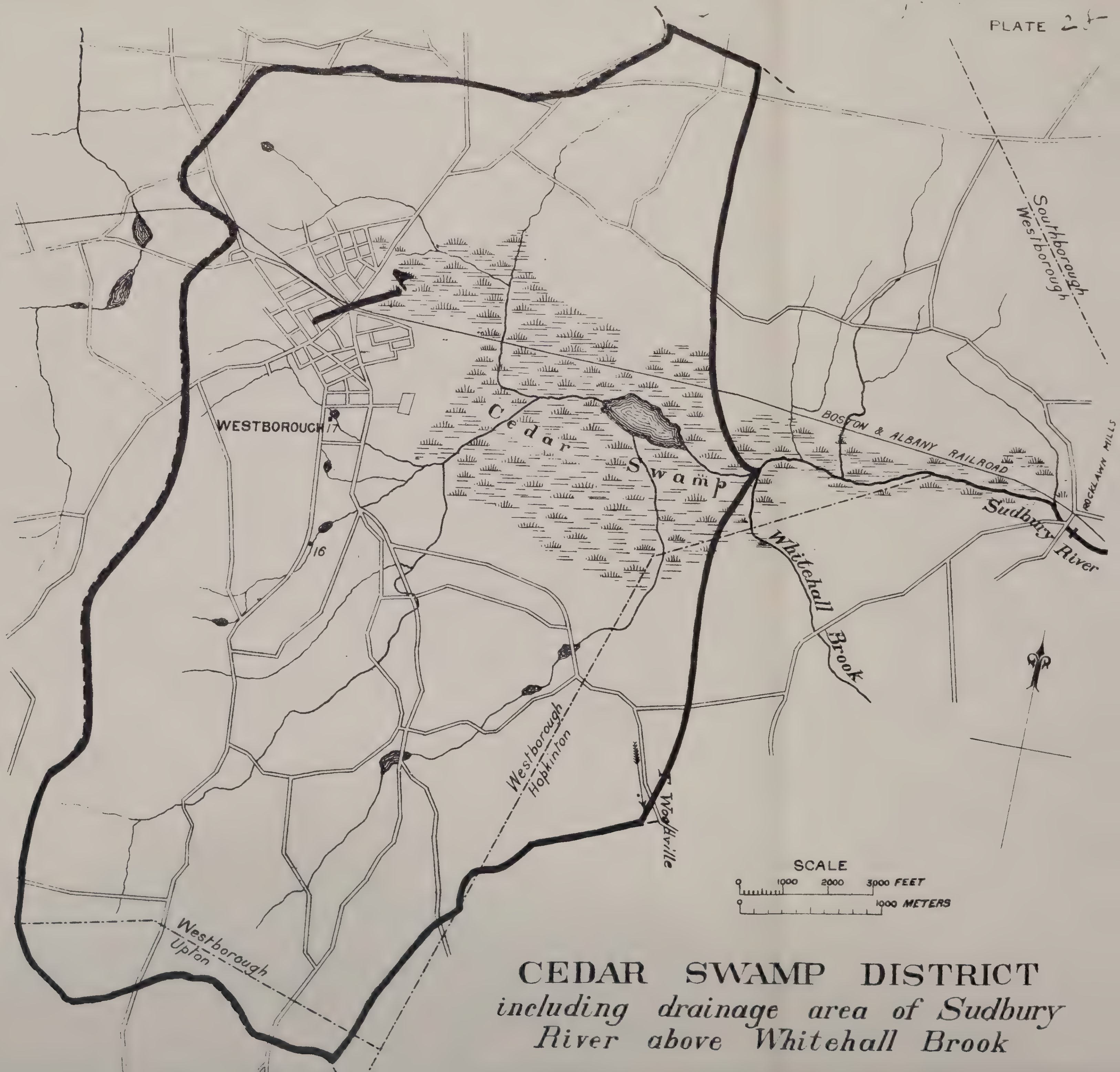
Whiteman Pond

Plate 25



also the upper end of the mill pond, and Plate 24 is a plan of the village. From the shoe shop (No. 1 on the plan), as well as from some other structures in the village, there is objectionable drainage into the stream. Among several cases of sewage contamination in the village by far the most important ~~case~~ is the shoe shop, No 1 on the plan whose privies are directly over the water. An injunction has been secured against the parties defiling the water in this way. I think it would be well for the City to secure the row of houses and remove them to a less objectionable site. The borders of the stream could then be protected. When the cases in the village of Woodville have all been remedied, the water from this district will be free from contamination by human drainage.

There remains another important matter to discuss. An examination of the plan of Whitehall Pond shows three small areas inside of the water line of the pond, in dotted lines. These were the original ponds. By the erection of the upper mill dam a very large area of land was flooded, causing an enormous amount of shallow flowage. From this area the stumps and vegetable matter were not removed. They add a peaty color, and otherwise injure the quality of the water. Plates No. 25 and 26 give an excellent idea of the character of these large areas. From a sanitary point of view, I believe that it would be of advantage to the City to have this objectionable shallow flowage remedied.



CEDAR SWAMP DISTRICT
including drainage area of Sudbury River above Whitehall Brook

Cedar Swamp District.

Cedar Swamp District includes the drainage of Sudbury River above the confluence of Whitehall Brook. The area is 9.30 square miles, 0.59 in Hopkinton, 0.35 in Upton and 8.36 in Westborough. Twenty-eight per cent. of this area is wooded. The population is 4270, all in the town of Westborough. The population per square mile is 462. There are about a thousand people in Westborough village employed in manufactures, most of them in two straw shops and two boot shops. The numbers employed vary in different seasons of the year.

Topographically this district is an exceedingly interesting one, as will be seen by an inspection of Plate 2 and Plate 28. Around the borders of the watershed are drumlins and other hills containing bowlder clays, and in the upper portions of the brooks the water is almost colorless. The water flows down into an extensive swamp called Cedar Swamp, and assumes in the lower portions of the brooks a peaty color from contact with vegetation. The geological map shows that the flat portion of the district, including the swamp, is composed almost entirely of gravel and sand, and if this is a correct classification, the mud of Cedar Swamp can only be superficial. Soundings taken under my direction several years ago show this to be the case and that it will probably not be a difficult matter to construct a canal either

Plate 29

Cedar Swamp.

PLATE.


WESTBOROUGH
OLD DRAINS ARE SHOWN THUS
SCALE
100 0 100 200 300 400 FEET
0 50 100 METERS
Magnetic
N
EAST MAIN ST.
WINTER ST.
MILK ST.
GROVE ST.
WEST MAIN ST.
CENTRAL ST.
SOUTH ST.
BRIGHAM ST.
COTTAGE ST.
ELM ST.
BOSTON & ALBANY R.R.
H. BERNARD & CO. STRAW SHOP.
C. WHITNEY
CEDAR SWAMP
1
2
3
4
5
6
7
8
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10
11
12
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through or around the swamp so as to lower the water table to the gravel and carry the nearly colorless waters of the sources to the main river without contact with vegetation. An extended survey of this whole region is now under way and the plans will be perfected as soon as possible. I know of no measure that promises better results for the improvement of the color of the Sudbury water. I consider it of importance to obtain possession of land on the borders of several of the brooks and water courses in the neighborhood of Westborough before the taking of the Rockland Mill dam.

Plate No. 29 is from a photograph taken from a point near the Boston and Albany Railroad.

The village of Westborough is situated on the westerly border of Cedar Swamp. Outside the village there are no serious cases of sewage pollution in this district. A plan of a portion of Westborough is shown on Plate 30. A number of years ago some drains were built in the streets, as shown by red lines. These were used only for surface drainage, and their outlet was into Cedar Swamp. In 1874 a public water supply was introduced from Sandra Pond in the southerly part of the town not far from the Hopkinton line. The average daily consumption ~~was~~ has increased to about 250,000 gallons. Soon after the introduction of this water connections with the drains in the streets were made for the purpose of carrying off the foul water from the buildings. As a natural con-

sequence the outlet at Cedar Swamp has shown unmistakable chemical evidence (Table IX No. 9) of the addition of sewage. Bernard's Straw Shop, shown on the plan and numbered 9,is a large establishment with a capacity of a thousand hands. It has a direct connection with the brook; the whole of the drainage from 13 water closets, 20 sinks and dye stuffs passes into the swamp. This is one of the worst cases of pollution on the whole supply, and can be clearly seen by the eye without the aid of science.

Steps should be taken to abate this great evil at as early a day as possible. There is no doubt about the necessity of a sewerage system for the village of Westborough. The discharge of its sewage into the Sudbury River ~~cannot~~ should not be permitted any longer. Committees have been elected by the town from time to time to provide a system of sewerage and several plans have already been proposed. The following is an abstract from the report of the committee on sewerage in 1881 :

> At the annual March meeting in 1875 the town authorized the then Board of Road Commissioners to cause surveys and estimates to be made with a view to the introduction of a system of sewerage for the village. That Board procured the services of Messrs. Buttrick and Wheeler, civil engineers of Worcester, Mass., who made surveys and estimates proposing a main drain or sewer from the east side of the Common through Brigham Street to Cedar Swamp Brook, a distance of about 3,400 feet, at an estimated cost, exclusive of land damage, of $5,111, but no action resulted from that inquiry.

The above report contemplated discharging the drainage of Westborough into the Sudbury River, an outlet which I think all will agree is impracticable. Later, Messrs. Ball & Heald, of

Worcester, were employed as engineers to devise a system. They also recommended the same outlet. Later, Col. George E. Waring, Jr., of Newport, devised a third plan at a cost of $30,000. Mr. Waring says :

"I have assumed that, as the drainage runs to the Sudbury River, you will not be permitted to discharge the effluent into the brook without first purifying it. The circumstances are favorable to its purification on the flat bounded by the brook and Sudbury River, the course of the brook being slightly changed. The matter of purification will be simple and of little cost, being effected by a combination of an osier bed and an irrigation field. The osier bed is about one acre in area, and is simply a series of level ditches running back and forth between banks (made by excavating the ditches) the banks being planted with osier willows. The sluggish flow secured by this means will cause a deposit of solid matter, and, as experience has amply shown, the effect of the growth of the willows in purifying the sewage will be almost, if not quite, complete. To make the purification absolute, the two outlets of the osier bed discharge on the surface of an irrigation field of about four (4) acres, over which it will flow to surrounding ditches, discharging into the brook."

In 1885 Eliot C. Clarke, engineer, reported to the Massachusetts Drainage Commission as follows in reference to the action of the Town of Westborough :

The committee recommended that this plan should be adopted, but that a part of it only should be then constructed, leaving the remainder to be built from time to time as needed. No action was taken at that time, but the town has always considered that whenever sewers are built a method of disposal somewhat similar to that recommended by Mr. Waring should be adopted. A committee on sewerage is now in existence, and the town voted to make a start in constructing its sewerage system in the autumn of 1885. It was afterwards decided to postpone work until the spring of 1886, in order first to consider any recommendations which should be made by your Commission.

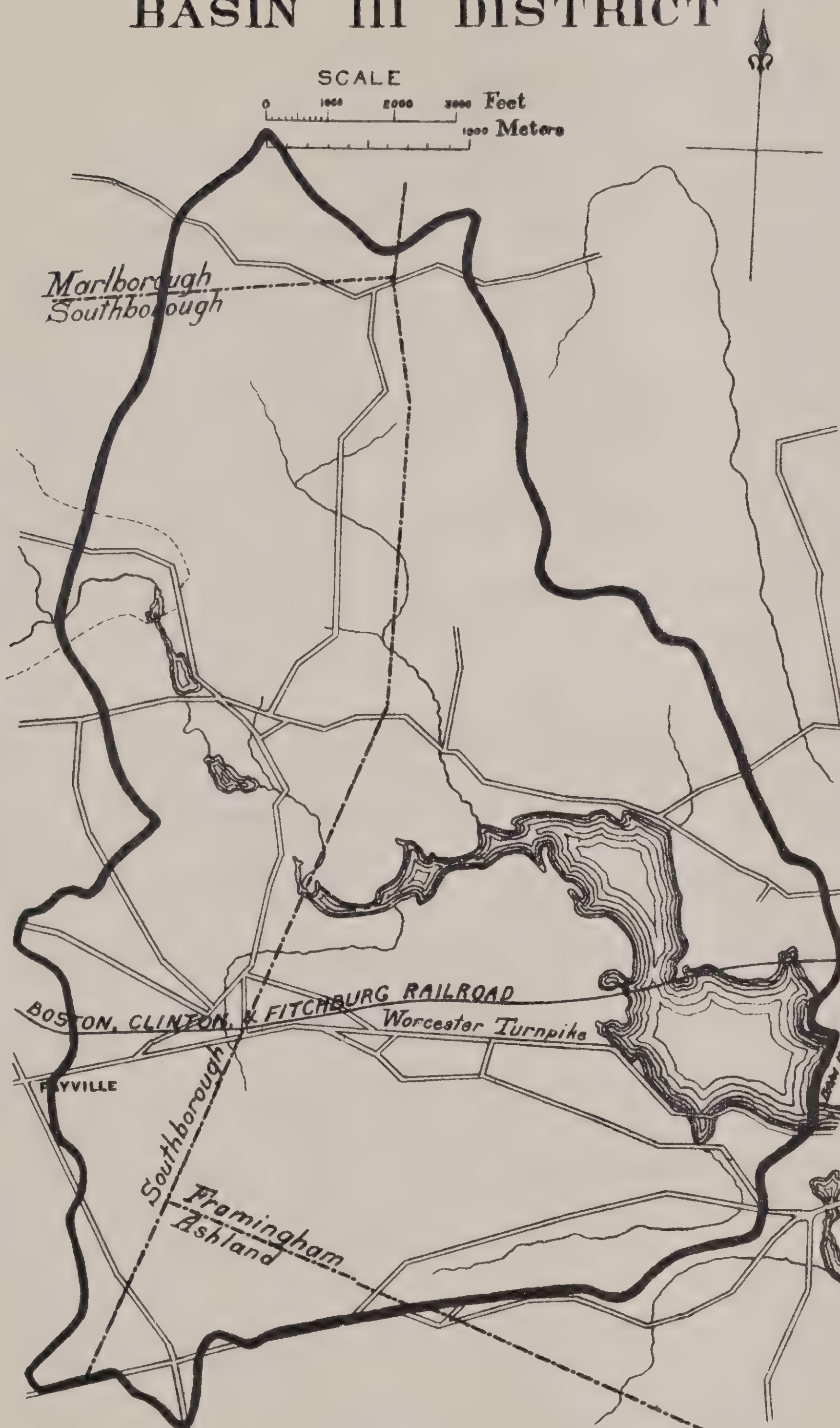
In my opinion there may be a reasonable doubt whether the scheme as proposed would prove satisfactory. The surface of the land on which it is proposed to discharge the sewage is so little elevated above that of the water in the neighboring swamp that the ground water is little if at all below the surface. The sewage which would be put on each acre would not therefore filter through aerated soil, so that the effluent which would escape into Boston's water supply would not be purified, or even entirely clarified. Turning imperfectly purified sewage into Boston's water supply probably would be considered a violation of the public statutes, and would almost certainly lead to litigation and injunctions on the part of the city. Should the discharge at this point prove to be illegal and be prohibited, the town would have a sewerage system without an inlet, or, at least, would be put to very great expense in altering the system so as to obtain a new outlet.

In this report Mr Clarke presented a another plan for disposing of the sewage.

At present this whole matter seems to be in statu quo. The situation of Westborough involves no difficulty in providing an outlet for its sewage away from the water supply of the City of Boston.

PLATE 31

BASIN III DISTRICT



B a s i n 3 D i s t r i c t .

This district comprises Basin 3 already constructed, and the lower portion of Stony Brook, the principal feeder of the basin. The total area is 6.20 square miles, of which 3.52 are in Framingham, 0.30 in Ashland, 2.17 in Southborough, and 0.21 in Marlborough. Twenty-four per cent. of this area is wooded. The population is 500, of which 210 are in Framingham, 76 in Ashland, 200 in Southborough and 14 in Marlborough, making a population of 87 per square mile, which is less ~~dense~~ than that of any other district.

There are no sources of pollution at present existing on this district. The brooks generally flow through pastures and woodlands and there are no villages. The only manufacturing establishment is a brickyard. Geologically, about two-thirds of the district is till, and one-third gravel, the gravel being around the basin. There are only two drumlins on the area, one near the head of the basin, the other a prominent feature very near Dam 3, rising out of the gravel.

PLATE 32

STONY BROOK DISTRICT

the drainage area of Stony Brook above Angle Brook

Stony Brook District.

This district comprises the drainage area of Stony Brook above Angle Brook. The area is 13.74 square miles, of which 9.34 are in Southborough, 1.71 in Westborough, 0.92 in Northborough, and 1.77 in Marlborough. Twenty per cent. of this district is wooded. The population is 1700, of which 950 are in Southborough, 500 in the Homeopathic Hospital at Westborough, 90 others in Westborough, 20 in Northborough and 140 in Marlborough. Average, 124 to the square mile. The surface is more irregularly varied than that of any other district, with drumlins, till and gravel. It has about one third gravel and two thirds till.

This district is a farming country with patches of woods. There are several villages in the district of which the most important are Fayville and Southborough Centre. From the former the drainage of a few houses goes into a small branch of Stony Brook, as shown on the diagram in the corner of Plate 32. No. 1 is Mawhinney's Shoe Shop, employing nearly 300 operatives, the only large manufactory in the district. It is expected that it will soon be removed to Hudson, Mass. There are also in the vicinity of Sawin's mill a few cases which endanger the purity of Deerfoot Brook. It will be desirable to secure land on the borders of some of these brooks without more delay than is necessary to make proper surveys.

A project for the introduction of water into Southborough has lately been presented by a committee of the town, who employed F. L. Fuller, C. E., of Boston, as their engineer.

Just outside of the Sudbury divide is situated the State Homeopathic Hospital for the Insane, as is shown on the map; but the sewage of this establishment is carried across the line into Boston's watershed and discharged on to a piece of land situated in the Stony Brook district. This is the only important source of contamination to the Brook in this district. Quite recently a second branch of the sewerage system has been built with its effluent discharging into Little Chauncey Pond outside of Boston's water shed. This system consists of an elaborately devised plan, but with filter beds hardly sufficient in area to take care of the sewage from the hospital. As nearly as I have been able to ascertain by personal inspection the sewage is discharged for eight months of the year into the Stony Brook water shed without proper purification. Even if it were a proper plan to put the outlet within the Boston water shed, there are no adequately prepared irrigation fields on the Stony Brook side of the divide, and the sewage is by no means purified before finding its way into the swamps at the head waters of the stream. An analysis of the Westborough Insane Hospital effluent at a time when it was discharging upon Boston's water shed, is to be found in table XV of the chemical tables. It can be seen at a glance that it is

ANGLE & BROAD MEADOW BROOKS DISTRICT


MARLBOROUGH
OLD DRAINS SHOWN THUS
SCALE
100 50 0 200 400 FEET
0 50 100 150 METERS
FITCHBURG RR MARLBOROUGH BR
MECHANIC
CENTRAL ST
LINCOLN ST
GAY ST
PLEASANT ST
MAIN ST
GIBBON ST
PARIS
GRANT ST
BROAD ST
DITCH
EMMETT ST
ORCHARD ST
SOUTH ST
LIBERTY ST
PROSPECT ST
NEWTON ST
WASHINGTON ST
SCHOOL ST
BOLTON ST
HIGH ST
COTTAGE ST
HOWE ST
OLD COLONY RR
FLORENCE ST
HILL ST
GARFIELD
Hardimans Brook
EAST MAIN ST
FRONT ST
HILDRETH ST
MAPLE ST
Magnetic

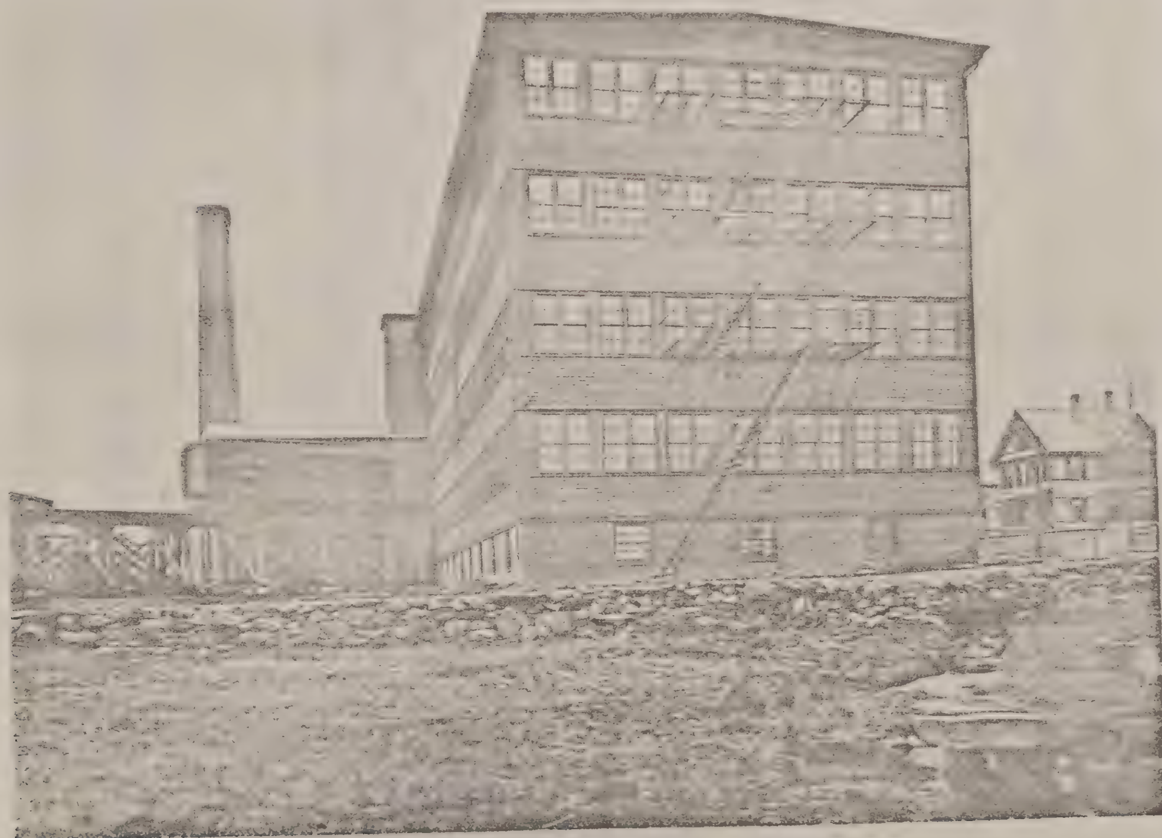
Angle and Broad Meadow Brooks District.

This district has an area of 7.88 square miles, of which 1.59 are in Southborough and 6.29 in Marlborough. Seventeen per cent. of this area is wooded. The population is 10,850, of which 10,800 are in Marlborough and 50 in Southborough. A very large proportion of the population of Marlborough is concentrated in the village. Marlborough is a great centre for the manufacture of boots and shoes; there are ~~about~~ 15 shops employing about 5,000 persons in this business. Other manufacturing is subordinate or very small.

Topographically, this district has a very marked character. Around its borders are groups of hills with drumlins among them; at the base of the hills there is gravel through which water percolates freely. This district includes a part of the lands that have been designated as desirable for the building of Basin 7 of the Sudbury supply~~; this basin is~~ which is represented on the plan in dotted lines. Excepting the village of Marlborough the district is at present an open farming country.

Hardiman's Brook and Angle Brook extend with numerous branches through the thickly settled portions of the town, and the houses, stores and manufacturing establishments which drain into the water are represented on Plate 34. The drainage from all these sources is so large in amount and of such a character

Hardiman's Brook, Marlborough.



Factory on Angle Brook.

as to pollute Stony Brook down to Basin 3; and it is shown in the
examinations
chemical portion of this report that it affects ~~the quality~~ of Basin 3 water to such a degree as to render it dangerous as a supply. In the report of the Medical Commission upon the sanitary qualities of the Sudbury, Mystic, Shawshine and Charles River waters (City document 102,- 1874- p. 44), is the following :

In the water of Angle Brook just below the town of Marlborough, we find a large amount of solids, both organic and volatile, and inorganic, and a comparatively large amount of chlorine. This can only be explained by the fact that it must receive, above the point from which the sample was collected, the drainage from Marlborough.

The analysis of the water of Angle Brook made for the Medical Commission will be found in table IX; another analysis will be found in tableX, and still another made for this report by Dr. Drown, in table XV. All the testimony is conclusive as to the danger from Marlborough drainage. In 1873 water was introduced from Williams Pond, and since that date the dangers have increased. The daily consumption of water is about 300,000 gallons.

Plate 36 is from a photograph showing one of the arms of Angle Brook coming out from beneath the Commonwealth Shoe Shop. It is difficult to insure that a stream in such a position shall receive no contamination from the building above it. Plate 35 is from a photograph of Hardiman's Brook where it passes through Marlborough. It speaks for itself.

For eight or ten years past projects of sewerage have been agitated in Marlborough. Edward S. Philbrick, Civil Engineer, made a report to the town in 1884, recommending the expenditure of about $150,000 for a sewerage system having its outlet at Marlborough Junction R. R. Station, quite near to the projected Basin 7 of the Sudbury system ~~of water supply~~. Another plan made by Mr. Clarke in 1885 for the Massachusetts Drainage Commission, ~~designed~~ provided an outlet upon irrigation fields situated just within the drainage area of Broad Meadow Brook. Your Board has recently made arrangements with the town to extend its sewer to another point, as shown on Plate 33, which is outside of Boston's water shed. A large portion of the cost of these works ~~will~~ has been contributed by the City of Boston. [illegible]

~~When the great bulk of~~ the sewage which now finds its way into Angle Brook ~~is~~ will soon be diverted into the new system, I shall look for a radical change in the chemical composition of this important feeder of Basin 3; but after the most perfect sewerage system that can be devised shall have been carried out I think it will be extremely difficult, even with the assistance of the officials of the town, to restore these brooks to their original condition of purity. It will still be ~~essential~~ necessary that proper ~~connections be~~ made with the street drains and that ~~proper~~ [illegible] sanitary regulations ~~be~~ enforced with reference to the brooks running through the town.

have recently been

I ~~recommend that a~~ Careful surveys be made of all the different ramifications of the brooks in Marlborough, to determine the expense of taking narrow strips of land on each side of the streams for the purpose of protecting them. Outside of the village the brooks are free from bad drainage. Certain pieces of land on the borders should be procured without delay, for Marlborough is a growing town and extending her population into the suburbs, and it will not be long before the low lands are built upon.

Summary Report by Districts

Districts	Direct Privy Drainage	Wash from privy	Cesspool - Privy drainage	Danger from Privy + Cesspool	Direct Sink drainage	Indirect Sink drainage	Danger from Sinks	Manure piles	Manufacturing Waste	Suspected	Remedied	Partially Remedied
Snake Brook					1	7		1	1	5		
Pegan Brook		6		2	3	19	10	11	1	20	69	
Dug Pond												
Course Brook						1	1					
Beaver Dam Brk.		14	4	8	11	59	7	10	3	7	7	
Farm Pond		1			5	1	1	1		3	6	
Bas. I & II & Cold Sp. Bk.				3		1	1				3	
East'n Sudbury	1	2		3	3	3	6	5		3	12	7
Indian Brook	1	2		1	3	6	1	4	1	2		
West'n Sudbury		2			3	1	4	3	2	2	3	3
Whitehall Brk.	2	8			5	7		1	1		3	1
Cedar Swamp	1	1		4	2	2	1		2	7	1	
Basin III												
Stony Brook		2			6	6		1		2	1	
Angle Brook	7	12		16	52	21	16	17	6	25	33	18
Totals	12	50	4	37	94	134	48	54	17	76	138	29

Total pollutions including those remedied & partially remedied — 693

— Do — excluding ——— " ——— Do. ——— " ——— 526.

I

Snake Brook

Direct Privy drainage	Wash from privy	Cesspool. Privy drainage	Danger from Privy & cesspl.	Direct Sink drainage	Indirect Sink drainage	Danger from Sinks	Manure piles	Manufacturing Waste	Suspected	Remedied
				11	2		15	11	7	
					3				10	
					4				12	
					5				13	
					6				14	
					9					
					16					
				1	7		1	1	5	

Total pollutions - 15

Pegan Brook

Direct Privy drainage	Wash from privy	Cesspool-Privy drainage	Danger from Privy & Cesspool	Direct Sink drainage	Indirect Sink drainage	Danger from Sinks	Manure piles	Manufacturing Waste	Suspected	Remedied
	29		9	80	10	2	15	8	3	1, 5,
	89		84	102	15	4	75		25	7, 12,
	92			122	68	6	81		30	13, 14,
	109				82	11	85		32	16, 17.
	113				83	76	89		47	18, 19,
	119				86	77	93		56	20, 21,
					87	103	109		71	22, 23,
					88	113	117		78	24, 26,
					89	118	119		79	27, 28,
					90	119	121		82	31, 33,
					94		123		83	34, 35,
					96				86	36, 37,
					97				87	38, 39,
					104				88	40, 41,
					108				96	42, 43,
					112				97	44, 45,
					114				105	46, 48,
					115				106	49, 50,
					120				114	51, 52,
									123	53, 54,
										55, 57,
										58, 59,
										60, 61,
										62, 63,
										64, 65,
										66, 67
										69, 69½,
										70, 72,
										73, 74,
										86½, 91,
										95, 98,
										99, 100,
										101, 107,
										110, 111,
										116.
	6		2	3	19	10	11	1	20	69

Total pollutions including those "remedied" & "partly remedied" .. 141

" Do " excluding " Do. " 72

III is Dug Pond.

IV Course Brook

Danger from Privy & Cesspool	Direct Sink drainage	Indirect Sink drainage	Danger from Sinks
3	2	3	1
1	1	1	1

Total pollutions -- 4

V

Beaver Dam Brook

Direct Privy drainage	Wash from privy	Cesspool. Privy drainage	Danger from Privy & Cesspool	Direct Sink drainage	Indirect Sink drainage	Danger from Sinks	Manure piles	Manufacturing Waste	Suspected	Remedied
	13	26	11	17	1, 6.	12,	13,	26	20	3
	17	57	14	18	7, 9.	22,	15,	64	51	4
	18	64	16	58	13. 15,	23,	25.	72	59	5
	25	72	47	59	19, 21,	84,	32.		69	8
	35		48	60	24, 25.	92.	41,		74	10.
	36		49	61	27, 28.	101,	62.		82,	73.
	41		76	62	29, 30.	102.	68.		89	88.
	42		101	67	31, 32.		77.			
	43			68	33, 34.		80,			
	57			77	35. 36,		91.			
	60			78	37, 38,					
	67				39, 40					
	68				41, 42.					
	80				43, 44.					
					45, 46					
					50, 52,					
					53. 54.					
					55. 56.					
					63, 65.					
					66. 69,					
					70, 75.					
					76. 79.					
					80, 81;					
					82, 83,					
					85, 86.					
					90, 93.					
					94, 95.					
					96. 97					
					98, 99					
					100					
	14	4	8	11	59	7	10	3	7	7

Total pollutions including those "remedied" 130

— " — Do — " — excluding — " — Do — " — 123

VI

Farm Pond

Direct Privy drain'ge	Wash from privy	Cesspool Privy drain'ge	Danger from Privy & Cesspl.	Direct Sink drainage	Indirect Sink drainage	Danger from sinks	Manure piles	Manufacturing Waste	Suspected	Remedied
	15			2	15	13	12		12	1
				4					13	3
				5					15	7
				6						8
				10						9
										11
										14
	1			5	1	1	1		3	6

Total pollutions including those "remedied" - 18

— " — Do — . — excluding — " — Do — . — - 15

Basins I & II & Cold Spring Brook

Direct Privy drainage	Wash from privy	Cesspool-Privy drainage	Danger from Privy & Cesspool	Direct Sink drainage	Indirect Sink drainage	Danger from Sinks	Manure piles	Manufacturing Waste	Suspected	Remedied	Partially Remedied
	8		4		3	5	7			1	
			5							2	
			6								
	1		3		1	1	1			2	

Total pollutions including those "remedied" - - 9
- " - Do - " - excluding - " - Do - " - - - 7

VIII Eastern Sudbury

Direct Privy drainage	Wash from Privy	Cesspool - Privy drainage	Danger from Privy & Cesspool	Direct Sink drainage	Indirect Sink drainage	Danger from Sinks	Manure piles	Manufacturing Waste	Suspected	Remedied	Partially Remedied
14	17		10	14	10	8	15		9	1	20
	18		11	15	11	18	20		13	5	23
			36	17	31	23	25		30	7	31
						25	29			12	32
						32	35			16	36
						35				22	10
										24	18
										26	
										27	
										28	
										33	
										34	
1	2		3	3	3	6	5		3	12	7

Total pollutions including those "remedied" & "partly remedied" - - 45

- Do. - excluding —— Do —— - - 26

IX Indian Brook

Direct Privy Drainage	Wash from privy	Cesspool-Privy drainage	Danger from Privy & Cesspool	Direct Sink drainage	Indirect Sink drainage	Danger from Sinks	Manure piles	Manufacturing Waste	Suspected	Remedied	Partially Remedied
5	1		9	1	2	12	2	8	6		
	3			3	4		10		7		
				8			11				
							12				
1	2		1	3	2	1	4	1	2		

Total pollutions . . . 17

X

Western Sudbury

Direct Privy drainage	Wash from privy	Cesspool - Privy drainage	Danger from Privy & cesspool	Direct Sink drainage	Indirect Sink drainage	Danger from Sinks	Manure piles	Manufacturing Waste	Suspected	Remedied	Partly remedied
	10			5	13	6	10	1	9	4	1
	13			11		10	11	2	13	7	2
				12		14	16			8	6
						15					
	2			3	1	4	3	2	2	3	3

Total pollutions including those remedied & partly remedied. 23

— Do — excluding — " — Do — . — — 17

XI Whitehall Brook

Direct Privy drainage	Wash from privy	Cesspool-Privy drainage	Danger from Privy & Cesspl.	Direct Sink drainage	Indirect Sink drainage	Danger from Sinks	Manure piles	Manufacturing Waste	Suspected	Remedied	Partially Remedied
1	1			1	6		4	1		2	11
3	4			3	8					12	
	5			4	9					15	
	6			5	10						
	7			7	11						
	8				13						
	9				14						
	10										
2	8			5	7		1	1		3	1

Total pollutions including "those remedied" & "partly remedied" 28

— Do — excluding — — Do — — 24

XII Cedar Swamp

Direct Privy drainage	Wash from privy	Cesspool-Privy drainage	Danger from Privy & Cesspool	Direct Sink drainage	Indirect Sink drainage	Danger from Sinks	Manure piles	Manufacturing Waste	Suspected	Remedied	Partially Remedied
11	8		2	11	9	15		9	1	7	
			5	17	16			10	3		
			9						4		
			15			#			6		
									12		
									13		
									14		
1	1		4	2	2	1		2	7	1	

Total pollutions including those "remedied" 21
—"— Do —"— excluding —"— Do —"— 20

XIII is Brew 3.

XIV

Stony Brook

Direct Privy drainage	Wash from privy	Cesspool – Privy drainage	Danger from Privy & Cesspl.	Direct Sink drainage	Indirect Sink drainage	Danger from Sinks	Manure pile	Manufacturing Waste	Suspected	Remedied
	1			2	4		14		15	
	11			6	3				16	
				7	5					17
				8	11					
				9	18					
				10	20					
	2			6	6		1		2	1

Total pollutions including those "remedied" 18 –

— Do — " — excluding — " — Do — " — 17

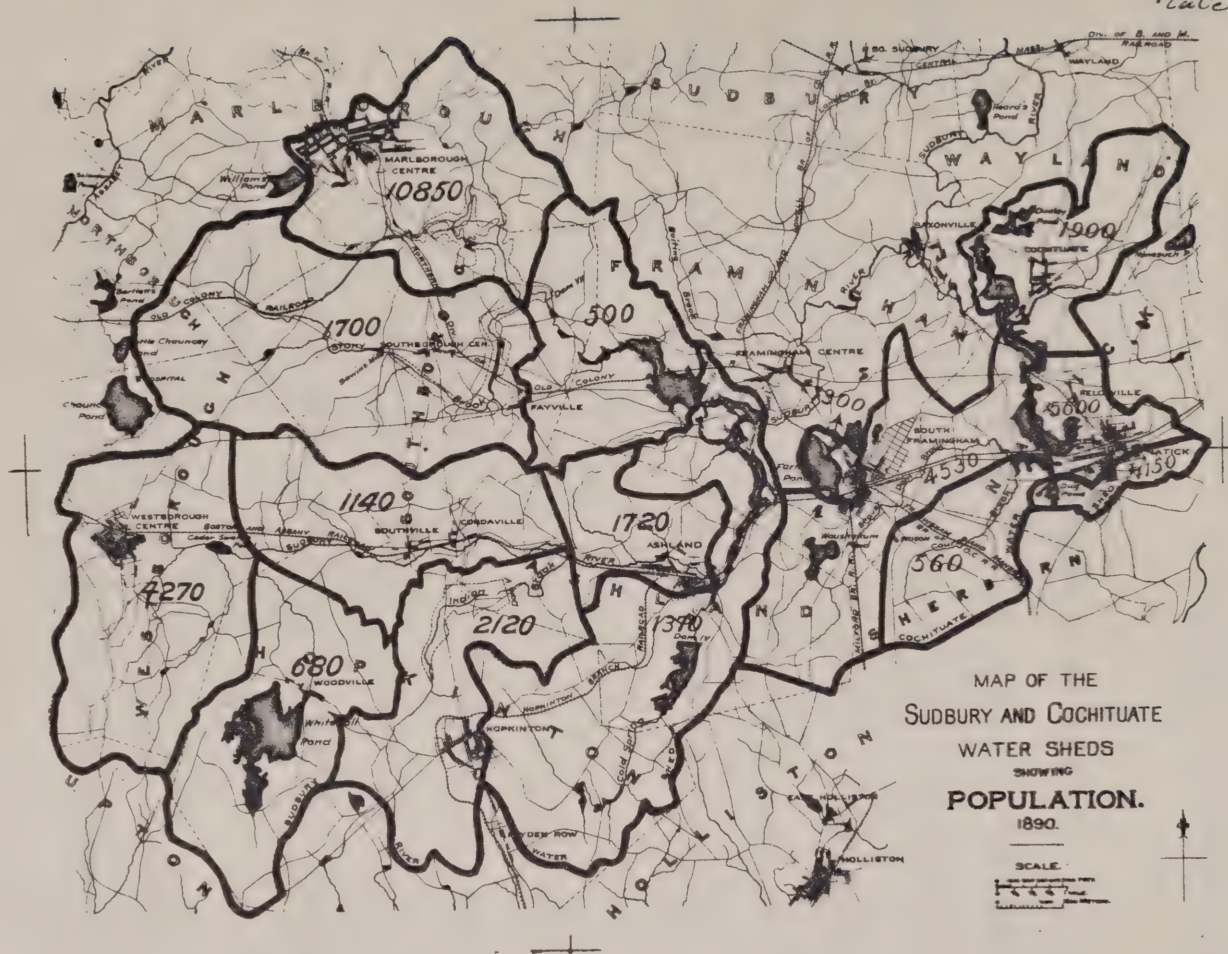
Angle & Broad Meadow Brooks District

Direct Privy Drainage	Wash from privy	Cesspool Privy drainage	Danger from Privy & Cesspool	Direct Sink drainage	Indirect Sink drainage	Danger from Sinks	Manure piles	Manufacturing Waste	Suspected	Remedied	Partly Remedied
34	3		37	5, 10,	3	30	2	20	3	1, 13,	2
47	5		49	12, 19½.	9	56	4	28	5	14, 21,	6
50	27		57	24, 25.	10	58	7	44	6	32, 39.	7
52	36		60	26, 27,	11	61	8	111	15	43, 48,	10
55	103		109	29, 31,	33	62	9	145	16	53, 54,	29
122	106		113	34, 36,	38	63	31	170	17	56, 59.	30
123	118		114	37, 45.	40	74	35		18	65, 66.	33
	119		115	47, 50.	71	75	42		19	67, 68,	38
	143		116	55, 57,	72	78	46		49	69, 70.	42
	144		120	83, 100	96.	82	51		73	76, 77,	45
	145		149	102, 104,	101	87	88		108	79, 80,	49
	167		157	105, 106,	103	91	104		113	81, 84,	56
			172	107, 108,	124	93	117		127	85, 86,	61
			173	117, 118,	129	94	118		133	89, 90,	62
			174	122, 123,	140	97	126		136	92, 95,	63
			175	125, 126,	145	153	128		137	99, 110,	71
				130, 131,	154		129		138	112, 158	91
				132, 139,	163				141		98
				142, 143	166				144		
				146, 147,	167				164		
				148, 149,	168				165		
				150, 151,					168		
				152, 155					169		
				156, 159.					171		
				160, 161.					176		
				162, 170							
7	12		16	52	21	16	17	6	25	34	18

Total pollutions including those "remedied" & "partly remedied" — 224

— Do — excluding — Do — 172

Plate 5.


MAP OF THE
SUDBURY AND COCHITUATE
WATER SHEDS
SHOWING
POPULATION.
1890.
SCALE
MARLBOROUGH CENTRE
10850
1700
500
1900
5600
4150
4530
900
560
1720
1140
1370
2120
680
1270
WESTBOROUGH CENTRE
SOUTHVILLE
CORDAVILLE
ASHLAND
HOPKINTON
WOODVILLE
HOLLISTON
EAST HOLLISTON
FAYVILLE
SOUTH FRAMINGHAM
FRAMINGHAM CENTRE
SAXONVILLE
COCHITUATE
NATICK
WAYLAND
SO. SUDBURY
Whitehall Pond
Williams Pond
Heard's Pond
Farm Pond
Waushakum Pond
Chauncy Pond

P o p u l a t i o n .

It has been generally conceded by Sanitarians that the objections to a given area for water supply increase with the increase of population.

The accompanying table presents a summary of the population in 1890 of the Cochituate, Sudbury and Farm Pond Watersheds, as estimated for this report and stated in part in the discussion of the several districts. The total population is 39,390. The total area of the three Watersheds, water surfaces excluded, is 90.21 square miles, so that the average population per square mile is 437.

On the Cochituate area the population is 13,740, on the Sudbury 24,350 and on the Farm Pond District 1300.

The area of the Cochituate water shed being 17.65 square miles water surfaces excluded, we have an average population of 778 to the square mile.

The area of the Sudbury water shed, water surfaces excluded, is 72.29 square miles, making an average population of 337 to the square mile.

The Cochituate is therefore more than twice as thickly settled as the Sudbury.

The area of the Farm Pond District is 0.27 square miles,

which gives that small district the dense population of 4815 to the square mile.

Taking the more concentrated portions of the large towns in all three water sheds, we find a total population of fully 30,000 people, as follows,

Natick	6500
South Framingham	5500
Ashland	1400
Hopkinton	1500
Westborough	3000
Marlborough	10000
Cochituate	1700
Insane Hospital	500
Sherborn Reformatory	300
TOTAL	30,400

The above estimate does not necessarily include the total population of the thickly settled portions. I have hadin view the concentration to which the application of sewerage systems might be practically made.

While at first glance the concentration of so large a number of people seems disadvantageous from a sanitary point of view, yet when we consider that by such concentration all the wastes of life, and manufacturing refuse can be more economically

removed by properly devised systems, such as those now contemplated, and in the case of South Framingham actually carried out, it will have its advantageous side.

If we ever provide adequate sewerage systems for the 30,000 population in the large villages, it will leave but about 10,000 people scattered about upon the water shed of 90 square miles, or 110 to the square mile.

Considering the population as it now exists, however, with all contributing their share to the pollution of the streams, it will be conceded I think, that the large population is a point against the choice of such an area for a water supply. The area of the Croton water shed is about 362 square miles, and the total population has been estimated by the State Board of Health of New York at 25,000, or 69 to the square mile.

Comparing the New York and the Boston water sheds on the basis of population we have,

Croton 69 to the square mile,

Boston 437 to the square mile,

and after taking out 30,000 of the concentrated portions of the Boston water sheds, we shall still have a larger population than the Croton as follows, Croton 69, Boston 110.

The lesson already taught by discussion of the District plans, is made all the more emphatic by the separate study of the subject of population.

Amount & Density of Population.

Districts	Wayland	Natick	Sherborn	Prison	Framingham	Ashland	Hopkinton	Southborough	Westborough	Hospital	Northborough	Marlborough	Total Population	Sq. Miles (water surfaces excluded)	Population per sq. mile
I Snake Brook	1700	175			25								1900	4·05	461
II Pegan Brook		5600											5600	1·82	3077
III Dug Pond		1150											1150	0·96	1198
IV Course Brook		92	168	300									560	3·46	162
V Beaver Dam Brook		163	222		4000	145							4530	7·36	615
Totals Cochituate water-shed													13740	17·65	778
VI Farm Pond					1300								1300	0·27	4815
VII Bas. I & II & Cold Sp. Bk.					240	737	393						1370	11·07	124
VIII Eastern Sudbury						1720							1720	3·36	512
IX Indian Brook						66	2054						2120	7·29	291
X Western Sudbury						75	65	900	100				1140	7·44	153
XI Whitehall Brook							674		6				680	6·55	104
XII Cedar Swamp									4270				4270	9·25	462
XIII Basin III					210	76		200				14	500	5·76	87
XIV Stony Brook								950	90	500	20	140	1700	13·70	124
XV Angle Brook								50				10800	10850	7·87	1379
Totals Sudbury water-shed													24350	72·29	337
Totals						—	—	—	—	—	—		39390	90·21	437

CHEMICAL DISCUSSION.

The importance of a series of good chemical analyses of a water will be disputed by no one familiar with the subject. Frankland, the eminent English authority, says, "though chemistry cannot prove any existing infectious property, it can prove, if existing, certain degrees of sewage contamination;" # and Wanklyn writes, "the albuminoid process is easily able to detect one part of albumen, gelatine, organic alkali, etc. mixed with ten million times its weight of water." ##

According to Wanklyn, ### "for most sanitary purposes a water analysis is complete when it includes these data;-

"Total solids.

"Chlorine.

"Free and albuminoid ammonia.

"Oxygen consumed in moist combustion.

"Poisonous metals".

To these data nitrites and nitrates have been added in recent years as indicating the last stages of the change of organic nitrogen into the inorganic state.

At the risk of repeating what has been set forth elsewhere, the significance of some terms used in the chemical tables and discussion will be briefly stated.

Water analysis P. 104.
Water analysis P. 10
Water analysis P. 11.

Color # is numerically designated according to the scale of the Nessler tubes, which is the same as that used for the ammonias. The figures increase as the color increases; 1.0 represents a distinct yellowish brown when seen in a depth of five or six inches; 2.0 represents a decided yellowish brown. Boston water averages 0.38.

Odor is found by shaking the water in a closed bottle about half full and then smelling it.

The quantities of the chemical constituents are expressed in parts per 100 000 by weight.

Fixed residue is the mineral matter.

Loss on ignition shows the weight of the organic matter.

Total solids means the sum of the mineral and organic matters including sediment and suspended matter, but when the amount of undissolved matter is excessive it is separated out by passing the water through a paper filter and determinations are made on both filtered and unfiltered water.

Albuminoid ammonia is nitrogenous matter capable of giving off ammonia in the process of decay. Dr. Thomas M. Drown has shown that this generally is one half the organic nitrogen in the water.

Free Ammonia means vegetable or animal matter in process of oxidation, or decay.

Dr. Wood's scale is different. The color increases in inverse ratio to the increase in figures, and the standard used is different.

Nitrites, a farther step in oxidation.

Nitrates, the completed change to the mineral state. Nitrates are harmless, but point to previous pollution.

Chlorine measures salt in the water. For one part of chlorine there are 1.65 parts of chloride of sodium, or common salt.

The importance of the ammonia determinations is very great. They show whether there is organic matter present capable of decomposing, or whether decomposition has already begun. Sewage is rich in free ammonia and in chlorine.

Though the chemist cannot always tell whether the origin of nitrogenous matter is animal or vegetable, inferences of great value can be drawn from a complete analysis. High color with a considerable amount of albuminoid ammonia and low free ammonia, points to vegetable pollution. High free ammonia without color indicates sewage contamination. Chlorine in water is subject to no change, and cannot be filtered out. The figures expressing its proportion can only vary by dilution, or evaporation of water. They are therefore a sure index of previous pollution.

Any one desiring to pursue these matters farther is referred to an instructive lecture by Dr. Thomas M. Drown, read before the New England Water Works Association (Vol. IV No. 2, Dec. 1889); also to the reports of the Mass. State Board of Health.

All the data which I have been able to collect from the

records of the Water Department and from other sources are embraced in a series of fifteen tables, as follows:-

I is an analysis made by A. A. Hayes in May 1837.

II two analyses by B. Silliman Jr. in 1845.

III several early measurements of the residues.

IV analyses by Prof. W. Ripley Nichols and others beginning in 1870.

V a series of analyses by Prof. Nichols of tap water from 1873 to 1881.

VI a ~~qualitative~~ mineral analysis.

VII analyses by Messrs. Merrick and Gray.

VIII ~~Prof.~~ Dr. Ira Remsen's analyses.

IX-XII analyses by Dr. Edward S. Wood.

XIII,XIV analyses by Dr. Thomas M. Drown for the Mass. State Board of Health.

XV Dr. Drown's analyses for the Boston Water Works.

The data of ~~the~~ tables XI & XIII have been plotted ~~upon diagrams,~~ so as to exhibit graphically the changes in the several elements from time to time. Plates 37 - 43 show Dr. Wood's quarterly analyses 1883-90; Plates 44 - 52 show Dr. Drown's monthly analyses 1887-9; the dotted lines show determinations upon water filtered through paper in the laboratory.

I have attempted by means of these data to answer the following questions.

<u>First</u>. What is the quality of the waters where they enter Lake Cochituate and the storage basins?

Second. What is the effect of storage in Lake Cochituate and the basins?

Third. What are the characteristics of the service or tap water at present supplied to the citizens of Boston?

Fourth. Does the Cochituate water show an increased contamination since its introduction in 1848?

Fifth. Does the Sudbury River water show any change since it was first taken?

FIRST.

What is the nature of the waters where they enter Lake Cochituate and the storage basins?

Lake Cochituate has sandy shores through which a large amount of water enters by percolation, and therefore with a high degree of purity. Its water gives less loss on ignition than any other except Dudley Pond, but its fixed residues and chlorine, being high, show that the water contributed by some of its feeders has been badly treated. An examination of the analyses of Beaver Dam and Pegan Brooks shows them to be highly contaminated. The former is one of the principal feeders of the Lake. Violent fluctuations in its quality are shown in the profiles. As already pointed out in the discussion of the Beaver Dam Brook District, the natural quality of this water is excellent, and by the remedy of certain abuses, which is there shown to be practicable, the water can be restored to its former purity. The other

feeders of the Lake yield good water.

Basins 2 and 3 are the most important supplies on the Sudbury River system. Taking the influents from Dr. Wood's table, we notice a marked difference between these two waters. For Basin 2 the lines of the diagram on plate 37 are more regular, showing a much more stable water than that of Basin 3; the chlorine particularly is nearly constant at about 0.40, while in Basin 3 it fluctuates from 0.40 to 1.20. Remembering the situations of these two basins, it is apparent that the sewage of Marlborough seriously injures the quality of Stony Brook as far down as Basin 3, while the small amount of sewage received from Westborough and elsewhere on the main Sudbury is insufficient materially to affect the water in Basin 2. A study of Dr. Drown's analyses leads to the same conclusion. The color determinations of Dr. Wood's analyses are not plotted, but by Dr. Drown's tables the color of Basin 2 influent is 1.09, and of Basin 3 influent 1.02, a very slight difference in favor of Basin 3. Here our knowledge of the sources from which the two waters are derived must assist us. As we have already seen, Basin 3 is fed from a rocky area with steeper slopes which give normally water with little color, while Basin 2 water is considerably colored by Cedar Swamp. The high color of Basin 3, therefore, is ground for suspecting contamination. By plotting together the curves of color of Basin 2 and Basin 3 influents, they are seen to correspond almost precisely, but the variations in Basin 2 occur a little sooner than

the corresponding variations in Basin 3, indicating that the cause of variation is farther away from Basin 3, or that it takes longer for the effect to reach Basin 3. It is remarkable that Basin 3 influent (Stony Brook) assumes a higher color than Basin 2 influent (Sudbury River) upon occasions, notably in June, July and October 1888, and May 1889.

Important lessons may be learned by careful color determinations such as those in the analyses of the State Board of Health, if such can be carried on for a series of years, including periods of drought as well as those of abundant rainfall.

The free ammonia in Basin 3 influent averages about three times as much as in Basin 2 influent, while the chlorine averages about twice as high, and nitrites and nitrates are also double those in Basin 2-influent. The foregoing facts in connection with our knowledge of the effect of these waters in producing algae, their taste, etc. lead to the conclusion that Basin 2 influent, though highly colored, is a very good water, but that water in the condition in which it comes to Basin 3 is unfit for a domestic supply. My biological examinations, showing the presence of euglena and entozoa in Angle Brook, coupled with turbidity when other streams are clear, confirm this opinion. Euglena have been traced to the head of Basin 3.

The fact that the chlorine in Basin 2 influent is uniform even in freshets, is of importance. The diagrams of Dr. Wood's analyses show no decrease of chlorine by dilution, nor

do those of Dr. Drown. In Basin 3 influent the chlorine varies inversely as the flow of the stream, which I have observed by plotting both curves on the same sheet. The inference is that the large proportion of chlorine in the small dry weather flow is owing to its taking in a considerable proportion of polluting matter from artificial sources, while the abundant flow of freshets being proportionately little contaminated, contains but a small proportion of chlorine. However great the flow there is no reason to suppose that the chlorine will be less than the normal proportion for natural water of this locality. Determining whether their chlorine is constant or fluctuating, may be useful as a test on a larger scale for other supplies.

If the albuminoid ammonia is plotted in the same manner it is found to vary approximately in inverse ratio to the flow. The color curve and that of albuminoid ammonia have close relationship to each other. The color is due to vegetable sources, such as leaves and peat. Fluctuation in the flow of the stream has an effect upon the density of color, and the color curve would probably follow a similar law to that just now mentioned with regard to chlorine and albuminoid ammonia were it not that the autumnal changes of vegetation increase the color at that season.

Basin 4, which feeds Basin 2, now receives by far the best water of the Sudbury supply. Its normal chlorine, and its comparative freedom from fluctuation, (exhibited to the eye by the nearly level lines of the profiles) are its points of ex-

101

cellence. Its high color shows the effect of some swamps on its feeders, ~~except for its color it is a better water than is drawn from the taps in Boston.~~

The smaller feeders of the several basins and other sources of supply are discussed chemically under the districts to which they belong.

Farm Pond cannot fairly be called a source of Boston's water supply, for by the construction of an aqueduct through the pond the supply is now independent of it. The contributing water shed is very small and the quality of the water depends upon what is passed into it from the basins above. It is so shallow and has such a muddy bottom that heavy winds make the water roilly. At present it is so rich in organisms that it has been thrown out of use.

SECOND.

What is the effect of storage in Lake Cochituate and the basins?

This is one of the most important of our inquiries and one of the best adapted to exhibit the admirable results attainable by careful chemical analysis.

Lake Cochituate. This lake has 800 acres of water surface, and the beneficial effects of storage are greater than in any other body of water on the works. The stability of the water is exhib-

 102

ited by the nearly level lines of its profiles, contrasting with those of Beaver Dam Brook. A study of the analyses, notably the small loss on ignition, reveals the enormous power of recuperation possessed by such a body of water. The very great increase noticeable in all the chemical impurities in 1884 by Dr. Wood's analyses (Plate 41) is largely accounted for by the excessive amounts of filth contributed to Beaver Dam Brook upon the starting of the Para Rubber Works. The color of the lake water is its best recommendation; it is 0.25 against 0.38 for the tap water in Boston. There is only one water on our supply which is less colored,- that is Dudley Pond with 0.13.

Basin 2. In Basin 2 the effect of storage upon the color is very slight, reducing it only from 1.09 to 1.01, showing that the color is permanent, and not indicating decay of substances in the water. The total residue is slightly reduced, but the volatile residue is increased a little, which, with other indications, shows permanence of form in organic matter. The free ammonia almost disappears becoming the same as in the Boston service pipes. Were nitrogenous matter present in sufficient quantity and condition to oxidize, the free ammonia would increase instead of diminishing. This is an important point in favor of Basin 2 water. The albuminoid ammonia, the chlorine and nitrites are unchanged, while the nitrates are reduced. The water is very soft. The indications are that the water is so good when

it comes into Basin 2 that storage has but small effect upon it.

Basin 3. In passing through Basin 3 the water changes its color from 1.02 to 0.87. ~~The color of Basin 3 water at the gate house is higher than that of the effluent of Basin 4.~~ The loss of color taken in connection with the accompanying changes of nitrogen indicates that the color is partly due to changeable organic matter, and confirms our suspicion ~~expressed above (p.)~~ that the influent is contaminated. The nitrites are very high in the water as it comes into the basin, which alone is a just cause of alarm. They are materially reduced in the effluent. This is true also of the residues of evaporation. The albuminoid ammonia is slightly reduced. The free ammonia which is about three times as high as that in Basin 2, is slightly increased in passing through the basin. Strange to say, while the chlorine at the influent is 0.57, at the effluent it is only 0.40; in summer the reduction may be as great as from 0.94 to 0.46 (August 1, 1888 Table XIII). As the basin is filled when the chlorine is low the effect of the high chlorine of the summer inflow is but slight on the effluent. In general, Basin 3 water is materially improved and rendered more stable by storage.

Basin 4. The effect of storage in Basin 4 is ~~probably~~ slight, but the data are insufficient for a full study. ~~I think~~ It is probable that analyses made regularly for ~~a~~ several years ~~or two~~ and especially

through a dry season will exhibit results which may change the method of managing this basin. It is probable that it may prove advantageous to use more of this water during the summer months than has been customary, and to waste the water that comes in the autumn months; but the management must be largely affected by other considerations such as the condition of the supply and the dryness of the season.

The effluent of Basin 4 is, except for its color, more uniform and better than any other on the supply, better even than the service or tap water in the city. Particular attention is invited to the flatness of the profiles (Plates 39 and 48), exhibiting both Dr. Wood's and Dr. Drown's results. The permanent and excellent qualities of the water are seen at a glance. In constructing this basin the ground was stripped of loam, and the flowage of vegetable matter avoided. The water is fifty feet deep near the dam, but it is not claimed that great depth is advantageous to purity. In this basin is an excellent opportunity to observe the normal changes in a large body of water due to the seasons and other causes. Among phenomena which have already been studied are the turning over of the water in the autumn due to the cooling of its surface, and the varying temperatures at the bottom, middle depth and surface throughout the year. The nitrates are low in Basin 4, and there is very little difference chemically in the water at different depths.

The mean of Dr. Drown's chlorine determinations for

Basin 4 is precisely the same as Prof. Silliman's chlorine determination for Lake Cochituate in 1845, which I regard as the normal chlorine of this vicinity.

Chestnut Hill Reservoir, where the Cochituate and Sudbury waters are mingled, has beneficial effects in making the water more steady and permanent before it passes into the distributing pipes. By storage The color is reduced to 0.38, exactly the same as found in the service pipes. The residues are also reduced.

THIRD.

What are the characteristics of the service or tap water?

Water drawn from the taps in Boston is in different condition from that at the sources of supply in that it is less liable to sudden fluctuations; the lines of the profiles are almost as even as those of Basin 4. The most marked change that the water undergoes in the pipes is the loss of free ammonia. According to Dr. Wood's seven year period, it is reduced from .0034 (C. H. Res.) to .0011 (tap water) and during the past two years from .0020 to .0007. According to Dr. Drown the reduction is from .0019 to .0008. The correspondence in these means is remarkable, covering many analyses and giving increased confidence in chemical results. The exact cause of this decrease in free ammonia is not clear, ~~but it corresponds to the slight increase in nitrates~~.

The albuminoid ammonia is practically unchanged, and so

are the more permanent forms of nitrogen, the nitrites and nitrates, so is also, of course, the chlorine.

An important characteristic of the Boston water is that it is remarkably soft at all times. Only those who have had experience with hard water can appreciate the value of a water uniformly soft.

A mean analysis of the tap water in Boston for two years Aug. '87-May '89 is given below. It must be said, however, that the rainfall in the past two years has been excessive, and that a period of dry years may make a slightly different showing.

Color	Residues Total	Loss on Ignition	Fixed	Free amm.	Alb. amm.	Chlorine	Nitrates	Nitrites	Hardness
0.38	4.98	1.47	3.51	.0008	.0207	0.41	.0206	.0002	1.9

An extract from a lecture by Dr. Drown before the Lowell Institute, Boston, Dec. 1889, is subjoined.

The composition of the Boston Water, as supplied to the consumer, is the result both of the mixture of the waters of various streams and of storage. The color is lighter than any of the waters of the Sudbury area and a little darker than Lake Cochituate. Its chlorine is lower than the Lake water and higher than that of the Sudbury River. Its free ammonia is uniformly low many analyses, month after month, showing none. The albuminoid ammonia is high, as is the case in all surface waters of this character; but the organic nitrogen which it represents has little or no tendency to change. This has been repeatedly shown by actual experiment, thus a sample of water from the faucet has been examined when freshly drawn, and a part set aside and examined at intervals of several weeks. In these later examinations the water has shown no change, that is to say there has been no development of ammonia from the organic nitrogen. This is but another way of saying that the water keeps well. It would scarcely be possible to have a better water than this is, in its general freedom from change. And it is somewhere in the processes of decay of nitrogenous matter in water, if I have correctly interpreted the meaning of the chemical analysis of water, that danger lies.

This statement of the <u>permanence</u> of the Boston Water does not ignore the fact that the waters of the Sudbury and Co-

chituate areas receive some direct and considerable indirect pollution from the population on these water sheds. But the time of storage in the basins on the Sudbury River, in Lake Cochituate, and in Chestnut Hill Reservoir is generally sufficient for the changes of decomposition to be completed before the water is supplied to the consumer; and thus it is that when we get the water there is no putrescible matter left in it.

FOURTH.

Can we trace increased effects of contamination in the Cochituate water?

Though a large mass of material has been collected in recent years, there is available absolutely no analysis of Boston water between 1845 and 1870, and there are other large gaps between 1873 and 1883, when regular quarterly analyses were begun. The imperfection of the early analyses is another stumbling block. Even within a few years chemical analyses were but crudely made; it was generally thought sufficient to ascertain the residues, which are among the least accurate of the chemical determinations. For many years chemists gave the amount of organic matter present but were unable to show in what stage of metamorphosis it existed. If only we had a few early analyses of the completeness now customary, we could trace much more accurately the changes that have occurred.

The longest series of analyses, plotted in the form of profiles, is to be found on plates 37 to 43 inclusive. The lower portion of Plate 41 shows the water of Lake Cochituate taken at

the gate house where it enters the aqueduct. A close inspection of these profiles shows that the chlorine line rises quite steadily from 1883 to 1889. The Chestnut Hill Reservoir and Service profiles confirm this observation. According to Dr. Wood's analyses the chlorine to-day is represented by 0.70. The mean of the seven years is exactly 0.56. From the profile we note that there has been an increase from 0.50 to 0.70 during the period named. It should be stated in this connection that the determinations of chlorine by Dr. Wood, though strictly comparable among themselves, are uniformly higher than those by Dr. Drown, owing to certain differences in methods. If we examine Prof. Nichols' analyses we find (Tables IV, V & VI) that in 1873 the chlorine in Cochituate water was about 0.30. Table VII when reduced gives 0.32 (Merrick & Gray Nov. 1873).

The evidence previous to this time is meagre, but goes to show, I think, that in 1846 when Boston first took the water the chlorine was about 0.25. Prof. Silliman's apparently careful analyses of two samples taken in 1845 (Table II), when properly reduced, show respectively 0.20 and 0.26 of chlorine, or a mean of 0.23. The chlorine to-day in Beaver Dam Brook when the Para Rubber Works are not running drops to 0.25 (see Table XV); and the chlorine in Snake Brook, the feeder of the lake nearest to the gate house is 0.33, while Dudley Pond within a few hundred feet of the lake and artificially connected with it shows 0.27. There exists evidence to prove that in 1846 there was no popula-

tion immediately on the borders of the brooks that feed the Lake. Testimony given in the trial of one of the Pegan Brook cases showed that in 1846, Natick was a small village and that between the railway station and the Lake, there were but two houses and those remote from the brook. We also know "that Beaver Dam Brook was a pure stream until within a few years."

The figures which we have obtained may be arranged thus:-

1846	From two analyses agreeing with the normal of the vicinity	0.23
1873	From many determinations by Prof. Nichols	0.30
1883-9	" " " " Dr. Wood	0.56
1887-9	or, if we take Dr. Drown's figures (Table XIII)	0.44

From all these facts I am led irresistibly to the conclusion that the chlorine in the Cochituate water has nearly doubled since 1846. This is most significant, for chlorine is the one unchangeable element which is traced without fail. From the situation of the Lake, it points distinctly to the effects of the wastes of life, sewage, and manufacturing refuse.

The discovery of the increase of the chlorine may prove of value as a guide to the Water Board in its efforts for correcting abuses, and the determinations of the chlorine in future years will serve as a test of the results of such efforts.

Fortunately the free ammonia does not increase or we might well be alarmed at an increase of organic matter in which decay was still in progress. From the analyses of the past seven

years I cannot find that the ammonias are either increasing or diminishing in the Lake. On going further back, the free ammonia shows no change; but there is ground for suspecting that the albuminoid ammonia has undergone some increase; the mean value of the albuminoid ammonia of the effluent of the Lake for the past two years is .0160, according to Dr. Wood, and .0207, according to Dr. Drown; but in 1879 it was .0142, and according to Prof. Nichols' figures, in Table V,.0118, the mean of eight samples in 1873.

There is good evidence of an increase in the total residue, for Prof. Nichols' means were generally lower than those now obtained for the Lake water. Examinations of Table IV, "at Gate House", show in 1873 a mean of 4.12 from two samples and in 1870, 4.20 from one sample, while Table V gives 4.86, the mean of eight samples in 1873. The present means for the Lake water, are 6.35, according to Dr. Wood, and 5.09, according to Dr. Drown. Thus an increase of one part has taken place during the period we are considering.

In this connection I may quote Prof. Nichols, who in discussing the effects of Natick drainage says, "unless attention is given in time to this state of affairs, the water supply of Boston must inevitably be affected in quality."

FIFTH.

Is the Sudbury River water also deteriorating in qual-

Basin 2, which corresponds in location with the first two of these groups, I find no evidence of deterioration in the main stream of the Sudbury. The last group corresponds to a mean between Basin 2 and Basin 3. Dr. Wood's examination for the Medical Commission made during the same season as the above by Prof. Nichols, shows that the water in the main Sudbury River was of quality very inferior to that obtained at present; it also shows that the water in Stony Brook was of quality superior to that obtained at present.

Taking everything together it seems to me probable that the water in the main stream of the Sudbury has not deteriorated in the last twenty years, but that Stony Brook has been undergoing a slight change for the worse.

~~I show in~~ The discussion of Shallow Flowage shows the improved condition chemically of the water in Basin 3 since the improvements made in 1886.

SUDBURY RIVER SUPPLY.—*Chemical Examination of Water from Sudbury River at Upper End of Reservoir No. 2, in Ashland.*

[Parts per 100,000.]

Number.	Date of Collection.	Date of Examination.	Appearance. Turbidity.	Appearance. Sediment.	Appearance. Color.	Residue on Evaporation. Total.	Residue on Evaporation. Loss on Ignition.	Residue on Evaporation. Fixed.	Ammonia. Free.	Ammonia. Albuminoid.	Chlorine.	Nitrogen as Nitrates.	Nitrogen as Nitrites.
	1887.												
18	May 31	June 1	Slight.	Slight.	1.50	4.01	1.58	2.43	.0019	.0291	-	-	-
227	June 30	July 1	Slight.	None.	1.00	5.17	1.80	3.37	.0038	.0310	.29	.0260	-
456	Aug. 1	Aug. 2	Very slight.	Slight.	0.90	5.10	1.17	3.93	.0034	.0275	.30	.0120	-
656	Aug. 31	Sept. 1	Very slight.	Slight, rusty.	1.20	6.35	2.15	4.20	.0029	.0392	.36	.0130	-
866	Oct. 3	Oct. 4	Very slight.	Slight.	0.70	5.70	1.65	4.05	.0018	.0282	.51	.0260	-
1075	Oct. 31	Nov. 1	Very slight.	Slight, earthy.	1.10	5.00	1.45	3.55	.0000	.0316	.48	.0100	-
1286	Nov. 30	Dec. 1	Very slight.	Very slight.	1.50	6.25	2.90	3.35	.0011	.0374	.48	.0150	-
	1888.												
1516	Jan. 2	Jan. 3	Distinct.	Slight, earthy.	1.00	4.47	1.82	2.65	.0037	.0277	.22	.0000	.0000
1722	Feb. 1	Feb. 2	Very slight.	Very slight.	1.50	5.70	2.25	3.45	.0049	.0244	.32	.0200	.0000
1932	Mar. 1	Mar. 2	Very slight.	Very slight.	0.80	4.65	1.85	2.80	.0002	.0259	.27	.0150	.0000
2139	Apr. 2	Apr. 3	Distinct.	Slight, earthy.	0.80	3.10	1.10	2.00	.0008	.0215	.19	.0080	.0001
2333	May 1	May 2	Slight.	Very slight.	1.10	3.85	1.85	2.00	.0000	.0278	.29	.0100	.0003
2544	June 4	June 4	Slight.	Slight.	1.40	4.85	2.30	2.55	.0004	.0372 .0350	.28	.0070	.0003
2695	July 2	July 3	Slight.	Slight.	1.30	5.00	2.25	2.75	.0020	.0288 .0288	.33	.0180	.0001
2868	Aug. 1	Aug. 3	Slight.	Slight.	0.85	4.50	1.65	2.85	.0026	.0284 .0234	.31	.0030	.0002
3045	Sept. 4	Sept. 5	Slight.	Slight.	1.80	6.75	2.55	4.20	.0048	.0444 .0380	.30	.0070	.0001
3299	Oct. 1	Oct. 2	Slight.	Slight.	2.00	5.70	3.15	2.55	.0014	.0390 .0350	.30	.0070	.0003
3475	Oct. 31	Nov. 1	None.	Very slight.	1.10	4.85	2.35	2.50	.0002	.0254 .0242	.35	.0080	.0002
3633	Dec. 3	Dec. 4	Very slight.	Slight, brown.	0.60	3.70	1.75	1.95	.0000	.0208 .0194	.31	.0180	.0002
	1889.												
3803	Jan. 1	Jan. 2	Very slight.	Slight, earthy.	0.60	3.35	1.20	2.15	.0000	.0170 .0158	.27	.0110	.0004
3957	Feb. 4	Feb. 5	Slight.	Slight.	0.60	3.40	1.10	2.30	.0006	.0206 .0176	.27	.0100	.0002
4200	Mar. 4	Mar. 5	Very slight.	Very slight.	0.70	3.45	1.15	2.30	.0004	.0198 .0166	.30	.0190	.0003
4443	Apr. 1	Apr. 2	Very slight.	Very slight.	0.70	3.35	1.25	2.10	.0006	.0196 .0196	.27	.0070	.0003
4598	May 1	May 2	Slight.	Considerable.	1.40	4.55	2.20	2.35	.0012	.0326 .0290	.27	.0050	.0003
Av.	....	....	....	....	1.09	4.95	1.80	3.15	.0016	.0283	.31	.0123	.0002

Hardness in May, 1888, 1.4. Odor, generally faintly vegetable, seldom mouldy and disagreeable.—The samples were collected from the river near the old dam at upper end of Reservoir No. 2, at a depth of one foot beneath the surface.

Microscopical Examination.

	1888. June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.	1889. Jan.	Feb.	Mar.	Apr.	May.
1. Blue-green Algæ, ...	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
2. Other Algæ, ...	5.1	2.0	0.8	0.5	0.4	0.1	0.1	0.9	1.1	0.9	2.1	0.4
3. Fungi, ...	2.1	pr.	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
4. Animal Forms, ...	0.1	0.2	1.7	0.3	pr.	0.0	0.0	pr.	0.0	0.1	0.3	0.3

Groups and principal genera of organisms observed: 2. Palmellaceæ; Zoosporeæ; Desmidiaceæ; Diatomaceæ, *Stauroneis*, *Synedra*; Zygnemaceæ. 3. Schizomycetes, *Crenothrix*. 4. Protozoa, *Dinobryon*; Spongiaria; Rotifera; Entomostraca.

In the other 14 Tables, see Portfolio

SUDBURY RIVER SUPPLY. — *Chemical Examination of Water from Reservoir No. 2, in South Framingham.*

[Parts per 100,000.]

Number.	Date of Collection.	Date of Examination.	Appearance. Turbidity.	Appearance. Sediment.	Appearance. Color.	Residue on Evaporation. Total.	Residue on Evaporation. Loss on Ignition.	Residue on Evaporation. Fixed.	Ammonia. Free.	Ammonia. Albuminoid.	Chlorine.	Nitrogen as Nitrates.	Nitrogen as Nitrites.
	1887.												
19	May 31	June 1	Decided.	Slig't, rusty.	1.40	4.60	2.38	2.22	.0024	.0297	–	–	–
234	June 30	July 1	Slight.	Slight.	1.30	5.17	1.72	3.45	.0039	.0365	.29	.0060	–
457	Aug. 1	Aug. 2	Slight.	Slight.	0.90	5.12	1.90	3.22	.0004	.0293	.31	.0070	–
657	Aug. 31	Sept. 1	Slight.	None.	0.80	4.95	1.72	3.23	.0006	.0335	.30	.0000	–
867	Oct. 3	Oct. 4	Slight.	Consid'ble.	1.30	5.57	2.20	3.37	.0006	.0398	.41	.0070	–
1076	Oct. 31	Nov. 1	Slight.	Slight.	1.00	4.05	1.05	3.00	.0012	.0320	.34	.0030	–
1287	Nov. 30	Dec. 1	Slight.	Slight.	0.90	5.10	2.10	3.00	.0018	.0340	.36	.0060	–
	1888.												
1517	Jan. 2	Jan. 3	Very slight.	Very slight.	1.60	6.05	2.35	3.70	.0026	.0350	.36	.0100	.0000
1723	Feb. 1	Feb. 2	Very slight.	Very slight.	1.30	6.05	2.80	3.25	.0012	.0258	.32	.0250	.0000
1931	Mar. 1	Mar. 2	Slight.	Very slight.	0.80	4.25	1.75	2.50	.0003	.0243	.23	.0150	.0000
2142	Apr. 2	Apr. 3	Very slight.	Very slight.	0.70	3.05	1.15	1.90	.0000	.0183	.20	.0080	.0001
2334	May 1	May 2	Distinct.	Very slight.	0.90	3.55	1.50	2.05	.0000	.0268	.35	.0120	.0003
2553	June 6	June 7	Slight.	Considerable.	1.30	4.20	1.90	2.30	.0002	.0324 .0240	.29	.0040	.0001
2713	July 5	July 6	Distinct.	Considerable.	1.00	4.55	2.15	2.40	.0006	.0300 .0224	.30	.0070	.0000
2867	Aug. 1	Aug. 3	Distinct.	Slight, green.	0.90	4.95	1.80	3.15	.0000	.0344 .0244	.34	.0030	.0001
3046	Sept. 4	Sept. 5	Distinct.	Considerable, green.	0.70	4.55	2.00	2.55	.0000	.0398 .0278	.25	.0050	.0001
3293	Oct. 1	Oct. 2	Very slight.	Very slight.	1.70	5.70	2.85	2.85	.0008	.0428 .0396	.29	.0070	.0002
3476	Oct. 31	Nov. 1	Slight.	Very slight.	1.50	4.85	2.15	2.70	.0000	.0308 .0270	.36	.0080	.0002
3634	Dec. 3	Dec. 4	Slight.	Slight.	0.60	3.80	1.70	2.10	.0002	.0198 .0188	.31	.0180	.0003
	1889.												
3804	Jan. 1	Jan. 2	Very slight.	Slight, earthy.	0.60	3.40	1.25	2.15	.0000	.0198 .0180	.27	.0130	.0006
3958	Feb. 4	Feb. 5	Slight.	Very slight.	0.60	3.35	0.85	2.50	.0000	.0220 .0182	.26	.0150	.0001
4201	Mar. 4	Mar. 5	Very slight.	Very slight.	0.55	3.25	1.20	2.05	.0008	.0218 .0190	.26	.0110	.0003
4444	Apr. 1	Apr. 2	Very slight.	Very slight.	0.90	3.20	1.20	2.00	.0008	.0190 .0176	.26	.0070	.0004
4599	May 1	May 2	Distinct.	Slight.	1.00	3.90	1.80	2.10	.0010	.0322 .0236	.27	.0070	.0002
Av.	....	....	....	....	1.01	4.79	1.88	2.91	.0008	.0296	.30	.0089	.0002

Hardness in May, 1888, 1.1. Odor, generally vegetable, occasionally mouldy and disagreeable. — The samples were collected from the reservoir, near the gate-house, at a depth of 8 feet beneath the surface. For monthly record of heights of water in this reservoir, see page 62.

Microscopical Examination.

	1888. June.	1888. July.	1888. Aug.	1888. Sept.	1888. Oct.	1888. Nov.	1888. Dec.	1889. Jan.	1889. Feb.	1889. Mar.	1889. Apr.	1889. May.
1. Blue-green Algæ, ...	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
2. Other Algæ, ...	4.2	16.2	6.0	1.8	1.1	0.1	pr.	0.5	pr.	0.1	3.8	4.6
3. Fungi, ...	0.0	0.0	pr.	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
4. Animal Forms, ...	pr.	0.8	1.5	0.2	pr.	1.2	pr.	pr.	0.0	2.0	0.2	pr.

Groups and principal genera of organisms observed: 2. Palmellaceæ; Zoosporeæ, *Scenedesmus;* Desmidiaceæ; Diatomaceæ, *Fragillaria, Synedra.* 3. Schizomycetes. 4. Protozoa, *Peridinium;* Rotifera; Entomostraca.

SUDBURY RIVER SUPPLY. — *Chemical Examination of Water from Stony Brook at Upper End of Reservoir No. 3, in Southborough.*

[Parts per 100,000.]

Number.	Date of Collection.	Date of Examination.	Appearance. Turbidity.	Appearance. Sediment.	Appearance. Color.	Residue on Evaporation. Total.	Residue on Evaporation. Loss on Ignition.	Residue on Evaporation. Fixed.	Ammonia. Free.	Ammonia. Albuminoid.	Chlorine.	Nitrogen as Nitrates.	Nitrogen as Nitrites.
	1887.												
21	May 31	June 2	Very slight.	Very slight.	1.80	7.45	3.83	3.62	.0058	.0427	0.46	-	-
228	June 30	July 1	Very slight.	Very slight.	1.10	6.62	2.35	4.27	.0039	.0388	0.50	.0100	-
458	Aug. 1	Aug. 2	Very slight.	Slight.	0.80	7.62	1.55	6.07	.0018	.0283	0.77	.0090	-
650	Aug. 31	Sept. 1	None.	Very slight.	1.10	8.92	1.90	7.02	.0036	.0446	0.86	.0130	-
868	Oct. 3	Oct. 4	Very slight.	Slight.	0.55	6.97	1.37	5.60	.0001	.0266	0.87	.0180	-
1077	Oct. 31	Nov. 1	Very slight.	Consid'ble, earthy.	0.75	8.40	2.65	5.75	.0000	.0370	1.08	.0160	-
1288	Nov. 30	Dec. 1	Distinct.	Slight.	1.20	8.20	2.85	5.35	.0057	.0355	0.66	.0230	-
	1888.												
1518	Jan. 2	Jan. 3	Decided.	Consid'ble, earthy.	0.75	5.25	1.90	3.35	.0136	.0289	0.26	.0200	.0005
1724	Feb. 1	Feb. 2	Very slight.	Very slight.	0.90	7.50	2.30	5.20	.0108	.0211	0.58	.0650	.0002
1933	Mar. 1	Mar. 2	Slight.	Very slight.	0.70	5.45	1.75	3.70	.0033	.0241	0.41	.0400	.0002
2141	Apr. 2	Apr. 3	Distinct.	Slight.	0.70	4.45	1.25	3.20	.0017	.0250	0.27	.0150	.0002
2335	May 1	May 2	Distinct.	Slight.	1.00	5.75	2.10	3.65	.0032	.0290	0.50	.0200	.0008
2545	June 4	June 4	Slight.	Slight.	1.90	6.20	2.45	3.75	.0014	.0442 .0392	0.38	.0250	.0006
2696	July 2	July 3	Distinct.	Slight.	1.70	6.85	2.60	4.25	.0040	.0370 .0336	0.61	.0120	.0009
2871	Aug. 1	Aug. 3	Very slight.	Very slight.	0.80	7.05	1.75	5.30	.0034	.0278 .0278	0.94	.0020	.0002
3047	Sept. 4	Sept. 5	Very slight.	Slight.	0.90	7.65	2.70	4.95	.0036	.0414 .0408	0.63	.0050	.0002
3294	Oct. 1	Oct. 2	None.	Very slight.	2.10	7.50	3.00	4.50	.0014	.0466 .0388	0.48	.0750	.0001
3477	Oct. 31	Nov. 1	Very slight.	Very slight.	1.90	6.20	2.30	3.90	.0006	.0296 .0282	0.55	.0300	.0002
3635	Dec. 3	Dec. 4	Very slight.	Very slight.	0.55	5.15	1.95	3.20	.0000	.0196 .0176	0.54	.0550	.0004
	1889.												
3805	Jan. 1	Jan. 2	Very slight.	Very slight.	0.60	4.45	1.30	3.15	.0036	.0178 .0152	0.44	.0550	.0008
3959	Feb. 4	Feb. 5	Slight.	Slight.	0.50	4.85	1.60	3.25	.0096	.0180 .0168	0.45	.0450	.0005
4202	Mar. 4	Mar. 5	Distinct.	Very slight.	0.60	5.15	1.55	3.60	.0202	.0224 .0192	0.50	.0400	.0010
4445	Apr. 1	Apr. 2	Very slight.	Very slight.	0.65	5.05	1.95	3.10	.0078	.0260 .0234	0.47	.0200	.0005
4600	May 1	May 2	Slight.	Slight.	1.45	5.70	2.40	3.30	.0036	.0358 .0326	0.41	.0150	.0006
Av.	....	....	....	....	1.02	6.88	2.15	4.73	.0047	.0309	0.57	.0274	.0005

Hardness in May, 1887, 1.8. Odor, generally faintly vegetable, seldom disagreeable. —— The samples were collected from Stony Brook about 50 feet below the first road above Reservoir No. 3, at a depth of one foot beneath the surface.

Microscopical Examination.

	1888. June.	1888. July.	1888. Aug.	1888. Sept.	1888. Oct.	1888. Nov.	1888. Dec.	1889. Jan.	1889. Feb.	1889. Mar.	1889. Apr.	1889. May.
1. Blue-green Algæ,	0.0	0.0	pr.	0.0	0.0	0.0	0.0	0.0	0.0	0.0	pr.	0.0
2. Other Algæ,	3.5	1.0	1.4	3.2	1.3	pr.	0.1	0.7	0.6	0.4	1.1	1.0
3. Fungi,	3.0	0.2	1.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	pr.	0.0
4. Animal Forms,	0.1	0.4	0.5	1.2	pr.	pr.	0.0	0.0	0.0	pr.	0.1	0.0

Groups and principal genera of organisms observed: 1. Cyanophyceæ. 2. Palmellaceæ; Zoosporeæ; Desmidiaceæ; Diatomaceæ, *Melosira*, *Tabellaria*. 3. Schizomycetes, *Crenothrix*. 4. Protozoa; Rotifera; Entomostraca.

SUDBURY RIVER SUPPLY. — *Chemical Examination of Water from Reservoir No. 3, in Framingham.*

[Parts per 100,000.]

Number.	Date of Collection.	Date of Examination.	Appearance. Turbidity.	Appearance. Sediment.	Appearance. Color.	Residue on Evaporation. Total.	Residue on Evaporation. Loss on Ignition.	Residue on Evaporation. Fixed.	Ammonia. Free.	Ammonia. Albuminoid.	Chlorine.	Nitrogen as Nitrates.	Nitrogen as Nitrites.
	1887.												
20	May 31	June 2	Slight.	Slight.	1.00	5.20	3.15	2.05	.0068	.0215	.38	.0260	–
229	June 30	July 1	Slight.	Slight.	1.10	6.17	1.90	4.27	.0058	.0284	.40	.0450	–
459	Aug. 1	Aug. 2	Slight.	Slight.	0.90	5.27	1.77	3.50	.0008	.0303	.36	.0070	–
858	Aug. 31	Sept. 1	Slight.	None.	1.00	5.35	1.47	3.88	.0216	.0338	.42	.0030	–
869	Oct. 3	Oct. 4	Slight.	Very slight.	1.00	5.67	1.92	3.75	.0068	.0352	.48	.0130	–
1078	Oct. 31	Nov. 1	Very slight.	Slight.	0.70	5.55	2.20	3.35	.0066	.0386	.51	.0100	–
1289	Nov. 30	Dec. 1	Very slight.	Slight.	0.70	5.15	1.75	3.40	.0030	.0351	.49	.0150	–
	1888.												
1519	Jan. 2	Jan. 3	Distinct.	Slight, white.	1.20	5.65	1.65	4.00	.0054	.0386	.45	.0150	.0001
1725	Feb. 1	Feb. 2	Very slight.	None.	1.30	6.50	2.40	4.10	.0072	.0257	.39	.0450	.0001
1934	Mar. 1	Mar. 2	Distinct.	Slight.	0.60	4.45	1.25	3.20	.0085	.0209	.31	.0250	.0002
2140	Apr. 2	Apr. 3	Decided.	Slight.	0.60	3.75	1.00	2.75	.0062	.0230	.27	.0180	.0002
2336	May 1	May 2	Distinct.	Considerable.	0.90	4.30	1.70	2.60	.0012	.0282	.35	.0200	.0003
2554	June 6	June 7	Very slight.	Slight.	1.20	5.10	1.95	3.15	.0022	.0326 .0252	.38	.0200	.0007
2714	July 5	July 6	Slight.	Slight.	0.60	5.05	2.20	2.85	.0010	.0274 .0252	.42	.0250	.0004
2870	Aug. 1	Aug. 3	Very slight.	Very slight.	1.10	3.10	1.10	2.00	.0040	.0278 .0254	.46	.0090	.0005
3048	Sept. 4	Sept. 5	Slight.	Slight, green.	0.70	5.45	1.90	3.55	.0020	.0336 .0256	.44	.0060	.0002
3295	Oct. 1	Oct. 2	Distinct.	Slight.	0.80	5.75	2.10	3.65	.0028	.0368 .0308	.43	.0090	.0002
3478	Oct. 31	Nov. 1	Slight.	Very slight.	2.20	5.95	2.30	3.65	.0024	.0294 .0266	.50	.0250	.0002
3636	Dec. 3	Dec. 4	Slight.	Slight, earthy.	0.55	4.75	1.90	2.85	.0028	.0218 .0182	.45	.0450	.0007
	1889.												
3806	Jan. 1	Jan. 2	Distinct.	Slight.	0.60	4.35	1.50	2.85	.0020	.0180 .0152	.37	.0180	.0006
3960	Feb. 4	Feb. 5	Slight.	Very slight.	0.50	4.60	1.55	3.05	.0034	.0222 .0200	.42	.0350	.0001
4203	Mar. 4	Mar. 5	Slight.	Very slight.	0.55	4.40	1.50	2.90	.0076	.0230 .0184	.34	.0400	.0003
4446	Apr. 1	Apr. 2	Very slight.	Slight.	0.50	4.10	1.30	2.80	.0074	.0238 .0194	.37	.0300	.0005
4601	May 1	May 2	Slight.	Considerable.	0.60	4.50	1.65	2.85	.0002	.0289 .0214	.42	.0200	.0006
Av.	....	....	....	....	0.87	5.25	1.85	3.40	.0049	.0285	.40	.0218	.0008

Hardness in May, 1888, 1.7. Odor, generally faintly vegetable, seldom disagreeable. —— The samples were collected from the reservoir, near the gate-house, at a depth of 8 feet beneath the surface. For monthly record of heights of water in this reservoir, see page 62.

Microscopical Examination.

	1888. June.	1888. July.	1888. Aug.	1888. Sept.	1888. Oct.	1888. Nov.	1888. Dec.	1889. Jan.	1889. Feb.	1889. Mar.	1889. Apr.	1889. May.
1. Blue-green Algæ, ...	pr.	0.1	0.1	pr.	0.2	pr.	0.0	0.0	0.0	0.0	0.0	0.0
2. Other Algæ, ...	13.5	119.6	4.7	4.5	12.5	0.5	pr.	0.3	pr.	0.9	1.4	3.3
3. Fungi, ...	pr.	0.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
4. Animal Forms, ...	0.9	0.8	0.1	0.1	1.9	pr.	0.0	0.0	0.0	0.4	0.5	4.4

Groups and principal genera of organisms observed: 1. Cyanophyceæ. 2. Palmellaceæ, *Chlorococcus;* Zoosporeæ; Desmidiaceæ; Diatomaceæ, *Asterionella, Melosira, Stephanodiscus, Synedra, Tabellaria.* 3. Schizomycetes. 4. Protozoa, *Dinobryon, Trachelomonas;* Rotifera; Entomostraca.

SUDBURY RIVER SUPPLY. — *Chemical Examination of Water from Reservoir No. 4, in Ashland, collected one foot beneath the surface.*

[Parts per 100,000.]

Number.	Date of Collection.	Date of Examination.	Appearance. Turbidity.	Appearance. Sediment.	Appearance. Color.	Residue on Evaporation. Total.	Residue on Evaporation. Loss on Ignition.	Residue on Evaporation. Fixed.	Ammonia. Free.	Ammonia. Albuminoid.	Chlorine.	Nitrogen as Nitrates.	Nitrogen as Nitrites.
	1887.												
15	May 31	June 1	Slight.	None.	1.00	3.63	1.95	1.68	.0011	.0231	–	–	–
235	June 30	July 1	Very slight.	None.	0.95	4.07	1.35	2.72	.0011	.0266	.28	.0065	–
460	Aug. 1	Aug. 2	Very slight.	None.	0.80	3.92	1.95	1.97	.0005	.0229	.24	.0030	–
651	Aug. 31	Sept. 1	Very slight.	None.	0.70	3.75	1.35	2.40	.0000	.0243	.24	.0000	–
863	Oct. 3	Oct. 4	Slight.	Very slight.	0.55	3.52	1.57	1.95	.0003	.0243	.24	.0030	–
1072	Oct. 31	Nov. 1	Slight.	Slight.	0.70	3.50	1.10	2.40	.0006	.0262	.26	.0020	–
1283	Nov. 30	Dec. 1	Slight.	Slight.	0.50	3.60	1.30	2.30	.0000	.0251	.26	.0050	–
	1888.												
1513	Jan. 2	Jan. 3	Slight.	Slight.	0.70	4.00	1.50	2.50	.0012	.0235	.22	.0060	.0000
1716	Feb. 1	Feb. 1	Slight.	Slight.	0.70	4.50	2.00	2.50	.0015	.0297	.20	.0100	.0000
1926	Mar. 1	Mar. 2	Slight.	Very slight.	0.70	3.85	1.60	2.25	.0003	.0323	.23	.0120	.0000
2136	Apr. 2	Apr. 3	Slight.	None.	0.45	3.18	0.95	2.23	.0018	.0248	.18	.0030	.0001
2330	May 1	May 2	Slight.	Very slight.	0.70	3.50	1.65	1.85	.0002	.0232	.21	.0050	.0002
2546	June 4	June 5	Distinct.	Considerable.	1.00	3.55	1.60	1.95	.0004	.0328 .0226	.22	.0060	.0001
2701	July 2	July 3	Slight.	Slight.	0.70	3.80	1.80	2.00	.0000	.0268 .0234	.25	.0050	.0001
2863	Aug. 1	Aug. 2	Slight.	Very slight.	0.90	3.65	1.80	1.85	.0002	.0286 .0254	.26	.0000	.0003
3042	Sept. 4	Sept. 5	Slight.	Slight.	0.50	4.00	1.85	2.15	.0000	.0256 .0212	.19	.0030	.0001
3289	Oct. 1	Oct. 2	Slight.	Slight, green.	0.70	3.85	1.60	2.25	.0008	.0286 .0232	.20	.0020	.0001
3487	Oct. 31	Nov. 2	Slight.	Very slight.	0.70	4.05	2.10	1.95	.0004	.0260 .0236	.26	.0050	.0001
3630	Dec. 3	Dec. 4	Very slight.	Very slight.	0.90	4.00	2.00	2.00	.0016	.0302 .0272	.26	.0080	.0002
	1889.												
3800	Jan. 1	Jan. 2	Slight.	Very slight.	0.90	3.55	1.65	1.90	.0016	.0274 .0252	.26	.0070	.0003
3954	Feb. 4	Feb. 6	Slight.	Slight.	0.75	3.40	1.30	2.10	.0008	.0228 .0178	.23	.0150	.0004
4197	Mar. 4	Mar. 5	Very slight.	Very slight.	0.80	3.40	1.65	1.75	.0012	.0210 .0182	.25	.0120	.0002
4440	Apr. 1	Apr. 2	Slight.	Very slight.	0.70	3.40	1.40	2.00	.0000	.0214 .0182	.21	.0070	.0002
4595	May 1	May 2	Distinct.	Slight.	0.60	3.65	1.50	2.15	.0000	.0256 .0204	.23	.0030	.0003
Av..	....	....	....	....	0.73	3.75	1.52	2.23	.0006	.0260	.23	.0056	.0001

Hardness in May, 1888, 1.3. Odor, generally vegetable, frequently disagreeable.—— The samples were collected from the reservoir, near the gate-house, at a depth of one foot beneath the surface. For monthly record of heights of water in this reservoir, see page 62.

Microscopical Examination.

	1888. June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.	1889. Jan.	Feb.	Mar.	Apr.	May.
1. Blue-green Algæ, ...	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
2. Other Algæ, ...	16.5	1.2	11.0	4.7	0.2	0.9	0.0	0.1	0.3	0.2	0.9	0.0
3. Fungi, ...	0.0	0.0	0.0	0.0	pr.	pr.	0.0	pr.	0.0	0.0	pr.	0.0
4. Animal Forms, ...	pr.	0.3	0.7	0.1	0.4	0.1	0.0	0.0	0.1	pr.	pr.	0.1

Groups and principal genera of organisms observed: 2. Palmellaceæ, *Chlorococcus;* Zoosporeæ, *Scenedesmus;* Desmidiaceæ, *Staurastrum;* Diatomaceæ, *Synedra.* 3. Schizomycetes. 4. Protozoa; Spongiaria; Rotifera; Entomostraca.

SUDBURY RIVER SUPPLY. — *Chemical Examination of Water from Reservoir No. 4, in Ashland, collected twenty feet beneath the surface.*

[Parts per 100,000.]

Number.	Date of Collection.	Date of Examination.	Appearance. Turbidity.	Appearance. Sediment.	Appearance. Color.	Residue on Evaporation. Total.	Residue on Evaporation. Loss on Ignition.	Residue on Evaporation. Fixed.	Ammonia. Free.	Ammonia. Albuminoid.	Chlorine.	Nitrogen as Nitrates.	Nitrogen as Nitrites.
	1887.												
16	May 31	June 1	Slight.	None.	0.80	3.66	1.33	2.33	.0008	.0197	–	–	–
236	June 30	July 1	Slight.	Very slight.	0.80	3.75	1.35	2.40	.0002	.0187	.26	.0065	–
461	Aug. 1	Aug. 2	Slight.	None.	0.75	3.47	1.47	2.00	.0006	.0166	.21	.0070	–
652	Aug. 31	Sept. 1	Very slight.	None.	0.70	3.72	1.32	2.40	.0000	.0274	.21	.0030	–
864	Oct. 3	Oct. 4	Very slight.	None.	0.60	3.65	1.45	2.20	.0002	.0232	.24	.0030	–
1073	Oct. 31	Nov. 1	Very slight.	Slight.	0.70	3.60	1.30	2.30	.0000	.0298	.25	.0030	–
1284	Nov. 30	Dec. 1	Very slight.	Slight.	0.50	3.70	1.45	2.25	.0008	.0241	.25	.0020	–
	1888.												
1514	Jan. 2	Jan. 3	Slight.	Slight.	0.70	4.05	1.40	2.65	.0019	.0255	.32	.0010	.0000
1717	Feb. 1	Feb. 1	Slight.	Slight.	0.70	4.35	1.70	2.65	.0026	.0251	.20	.0100	.0000
1927	Mar. 1	Mar. 2	Slight.	Slight.	0.50	4.25	1.70	2.55	.0030	.0263	.27	.0090	.0000
2137	Apr. 2	Apr. 3	Slight.	Slight.	0.70	4.65	1.45	3.20	.0167	.0260	.26	.0100	.0003
2331	May 1	May 2	Distinct.	Slight.	0.90	3.85	1.70	2.15	.0000	.0256	.21	.0050	.0002
2547	June 4	June 5	Very slight.	Considerable.	0.90	3.50	1.35	2.15	.0000	.0278 .0220	.22	.0030	.0001
2702	July 2	July 3	Distinct.	Slight.	0.40	3.65	1.10	2.55	.0006	.0252 .0214	.24	.0050	.0001
2864	Aug. 1	Aug. 2	Very slight.	Very slight.	0.90	3.90	1.75	2.15	.0004	.0250 .0242	.24	.0000	.0003
3043	Sept. 4	Sept. 5	Distinct.	Slight.	0.50	3.65	1.60	2.05	.0000	.0262 .0204	.16	.0030	.0001
3290	Oct. 1	Oct. 2	Slight.	Slight, green.	0.70	3.75	1.80	1.95	.0000	.0280 .0250	.19	.0020	.0001
3488	Oct. 31	Nov. 2	Slight.	Very slight.	0.75	4.00	1.85	2.15	.0000	.0274 .0268	.25	.0070	.0001
3331	Dec. 3	Dec. 4	Slight.	Slight.	0.90	3.85	1.85	2.00	.0012	.0262 .0240	.25	.0050	.0004
	1889.												
3801	Jan. 1	Jan. 2	Very slight.	Very slight.	0.90	3.85	1.70	2.15	.0010	.0264 .0210	.25	.0070	.0003
3955	Feb. 4	Feb. 6	Slight.	Slight.	0.75	3.40	1.25	2.15	.0014	.0220 .0172	.22	.0150	.0002
4198	Mar. 4	Mar. 5	Very slight.	Very slight.	0.80	3.60	1.70	1.90	.0010	.0212 .0176	.25	.0120	.0001
4441	Apr. 1	Apr. 2	Very slight.	Very slight.	0.70	3.40	1.40	2.00	.0000	.0210 .0186	.21	.0070	.0001
4596	May 1	May 2	Distinct.	Slight.	0.65	3.50	1.35	2.15	.0000	.0216 .0184	.22	.0050	.0002
Av.	....	....	....	....	0.72	3.89	1.47	2.42	.0014	.0244	.23	.0057	.0002

Hardness in May, 1888, 1.3. Odor, generally vegetable, frequently disagreeable. —— The samples were collected from the reservoir, near the gate-house, at a depth of 20 feet beneath the surface.

Microscopical Examination.

	1888. June.	1888. July.	1888. Aug.	1888. Sept.	1888. Oct.	1888. Nov.	1888. Dec.	1889. Jan.	1889. Feb.	1889. Mar.	1889. Apr.	1889. May.
1. Blue-green Algæ, ...	pr.	0.0	0.0	pr.	pr.	0.0	0.0	0.0	0.0	0.0	0.0	0.0
2. Other Algæ, ...	8.4	3.4	0.3	3.5	0.4	0.1	0.0	0.3	0.3	0.5	1.3	0.2
3. Fungi, ...	0.0	pr.	pr.	pr.	0.0	pr.	0.0	0.0	0.0	0.0	0.0	0.0
4. Animal Forms, ...	pr.	2.3	pr.	0.5	0.1	pr.	0.0	0.0	pr.	pr.	pr.	0.0

Groups and principal genera of organisms observed: 1. Cyanophyceæ. 2. Palmellaceæ; Zoosporeæ; Desmidiaceæ, *Staurastrum;* Diatomaceæ, *Synedra.* 3. Schizomycetes. 4. Protozoa, *Trachelomonas;* Spongiaria; Rotifera; Entomostraca.

SUDBURY RIVER SUPPLY. — *Chemical Examination of Water from Reservoir No. 4, in Ashland, collected near the bottom.*

[Parts per 100,000.]

Number.	Date of Collection.	Date of Examination.	Appearance. Turbidity.	Appearance. Sediment.	Appearance. Color.	Residue on Evaporation. Total.	Residue on Evaporation. Loss on Ignition.	Residue on Evaporation. Fixed.	Ammonia. Free.	Ammonia. Albuminoid.	Chlorine.	Nitrogen as Nitrates.	Nitrogen as Nitrites.
	1887.	1887.											
17	May 31	June 1	Slight.	None.	0.80	4.12	1.75	2.37	.0016	.0210	–	–	–
237	June 30	July 1	Slight.	Slight.	0.70	4.20	1.17	3.03	.0010	.0235	.26	.0040	–
462	Aug. 1	Aug. 2	Very slight.	Slight.	0.75	3.60	1.32	2.28	.0037	.0162	.17	.0070	–
658	Aug. 31	Sept. 1	Very slight.	None.	0.70	3.55	1.20	2.35	.0021	.0192	.18	.0070	–
	1887.	1887.											
865	Oct. 3	Oct. 4	Very slight.	Very slight.	0.75	3.67	1.35	2.32	.0019	.0201	.24	.0070	–
1074	Oct. 31	Nov. 1	Slight.	Slight.	0.50	3.85	1.55	2.30	.0006	.0352	.27	.0020	–
1285	Nov. 30	Dec. 1	Slight.	Slight.	0.40	3.70	1.50	2.20	.0005	.0262	.22	.0030	–
	1888.	1888.											
1515	Jan. 2	Jan. 3	Very slight.	Slight.	0.70	4.20	1.65	2.55	.0014	.0262	.19	.0030	.0000
1718	Feb. 1	Feb. 1	Slight.	Slight.	0.60	4.35	1.65	2.70	.0042	.0275	.20	.0120	.0000
1928	Mar. 1	Mar. 2	Very slight.	Slight.	0.60	4.40	1.65	2.75	.0032	.0270	.29	.0120	.0000
2138	Apr. 2	Apr. 3	Distinct.	Slight, earthy.	0.80	4.55	1.30	3.25	.0158	.0270	.29	.0100	.0003
2332	May 1	May 2	Distinct.	Slight.	0.80	3.80	1.70	2.10	.0004	.0226	.22	.0050	.0003
2548	June 4	June 5	Slight.	Slight.	0.80	4.25	1.75	2.50	.0000	.0242 .0206	.21	.0060	.0001
2703	July 2	July 3	Slight.	Slight.	0.70	3.55	1.95	1.60	.0008	.0244 .0192	.25	.0080	.0001
2865	Aug. 1	Aug. 2	Very slight.	Very slight.	0.90	4.05	1.60	2.45	.0010	.0254 .0168	.24	.0000	.0005
3044	Sept. 4	Sept. 5	Slight.	Considerable.	0.55	3.75	1.65	2.10	.0012	.0308 .0230	.17	.0020	.0001
3291	Oct. 1	Oct. 2	Distinct.	Slight, green.	0.60	3.50	1.50	2.00	.0000	.0242 .0236	.18	.0030	.0001
3489	Oct. 31	Nov. 2	Slight.	Very slight.	0.70	4.10	1.90	2.20	.0004	.0268 .0222	.25	.0050	.0001
3682	Dec. 3	Dec. 4	Very slight.	Very slight.	0.90	3.75	2.10	1.65	.0012	.0268 .0242	.27	.0050	.0003
	1889.	1889.											
3802	Jan. 1	Jan. 2	Slight.	Very slight.	0.90	3.80	1.75	2.05	.0008	.0270 .0228	.24	.0080	.0006
3956	Feb. 4	Feb. 6	Slight.	Slight.	0.75	3.45	1.30	2.15	.0016	.0210 .0184	.20	.0150	.0002
4199	Mar. 4	Mar. 5	Very slight.	Very slight.	0.80	3.50	1.45	2.05	.0012	.0216 .0182	.24	.0150	.0001
4442	Apr. 1	Apr. 2	Very slight.	Very slight.	1.00	3.40	1.40	2.00	.0002	.0190 .0186	.22	.0070	.0003
4597	May 1	May 2	Slight.	Slight.	0.75	3.55	1.55	2.00	.0008	.0228 .0178	.23	.0050	.0002
Av.	....	....	....	....	0.73	4.00	1.48	2.52	.0019	.0244	.23	.0066	.0002

Hardness in May, 1888, 1.4. Odor, generally vegetable, frequently disagreeable. — The samples were collected from the reservoir, near the gate-house, at a depth of 40 feet beneath the surface, with the exception of Nos. 1074, 1285, 1515 and 1718, which were collected at 38, 30, 34 and 38 feet respectively beneath the surface.

Microscopical Examination.

	1888. June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.	1889. Jan.	Feb.	Mar.	Apr.	May.
1. Blue-green Algæ,	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
2. Other Algæ,	3.8	0.4	0.1	0.7	0.8	1.1	pr.	0.4	0.1	0.1	1.0	0.0
3. Fungi,	0.0	0.0	0.0	pr.	0.0	pr.	0.0	pr.	0.0	0.0	pr.	0.0
4. Animal Forms,	pr.	0.3	pr.	0.1	0.2	0.2	0.0	pr.	pr.	0.0	0.2	0.0

Groups and principal genera of organisms observed: 2. Palmellaceæ; Zoösporeæ; Desmidiaceæ; Diatomaceæ, *Synedra*. 3. Schizomycetes. 4. Protozoa; Rotifera; Entomostraca.

Sudbury River Supply. — *Chemical Examination of Water from Farm Pond, in Framingham.*

[Parts per 100,000.]

Number.	Date of Collection.	Date of Examination.	Appearance. Turbidity.	Appearance. Sediment.	Appearance. Color.	Residue on Evaporation. Total.	Residue on Evaporation. Loss on Ignition.	Residue on Evaporation. Fixed.	Ammonia. Free.	Ammonia. Albuminoid.	Chlorine.	Nitrogen as Nitrates.	Nitrogen as Nitrites.
	1887.												
14	May 31	June 1	Slight, milky.	None.	1.00	4.70	2.15	2.55	.0090	.0236	–	–	–
231	June 30	July 1	None.	None.	0.80	5.35	1.35	4.00	.0060	.0275	.40	.0130	–
455	Aug. 1	Aug. 2	Slight.	None.	0.70	5.15	1.35	3.80	.0006	.0254	.38	.0030	–
	1887.												
660	Aug. 31	Sept. 1	Slight.	Slight, rusty.	0.50	5.90	1.62	4.28	.0004	.0327	.39	.0000	–
870	Oct. 3	Oct. 4	Distinct.	Slight.	0.75	5.40	1.75	3.65	.0125	.0383	.40	.0090	–
1079	Oct. 31	Nov. 1	Slight.	Considerable.	0.70	4.55	1.40	3.15	.0006	.0348	.36	.0010	–
1290	Nov. 30	Dec. 1	Slight.	Slight.	0.90	4.85	1.95	2.90	.0010	.0290	.34	.0040	–
	1888.												
1520	Jan. 2	Jan. 3	Very slight.	Slight, white.	0.70	5.65	2.00	3.65	.0016	.0330	.39	.0080	.0000
1726	Feb. 1	Feb. 2	Very slight.	None.	1.00	5.80	2.20	3.60	.0045	.0245	.32	.0280	.0000
1935	Mar. 1	Mar. 2	Distinct.	Very slight.	0.60	5.35	1.30	4.05	.0079	.0232	.42	.0250	.0002
2143	Apr. 2	Apr. 3	Decided.	Considerable, white.	0.45	4.35	1.25	3.10	.0068	.0236	.34	.0180	.0003
2337	May 1	May 2	Decided.	Slight.	0.50	4.20	1.30	2.90	.0016	.0238	.34	.0120	.0004
2555	June 6	June 7	Slight.	Considerable, white.	0.70	4.75	1.65	3.10	.0034	.0264 .0174	.42	.0250	.0005
2715	July 5	July 6	Distinct.	Slight.	0.50	4.95	1.65	3.10	.0084	.0248 .0246	.40	.0200	.0003
2869	Aug. 1	Aug. 3	Slight.	Slight, green.	0.85	5.10	1.70	3.40	.0030	.0280 .0222	.37	.0070	.0002
3049	Sept. 4	Sept. 5	Slight.	Slight, white.	0.60	4.25	1.60	2.65	.0032	.0258 .0234	.27	.0030	.0001
3292	Oct. 1	Oct. 2	Slight, milky.	Slight.	0.60	5.00	1.60	3.40	.0116	.0312 .0274	.34	.0120	.0004
3479	Oct. 31	Nov. 1	Slight.	Very slight.	1.20	5.25	2.25	3.00	.0086	.0252 .0242	.39	.0200	.0003
3637	Dec. 3	Dec. 4	Slight.	Very slight.	0.75	5.65	1.60	4.05	.0098	.0226 .0208	.48	.0300	.0004
	1889.												
3807	Jan. 1	Jan. 2	Slight.	Slight.	0.50	5.25	1.65	3.60	.0040	.0186 .0182	.50	.0250	.0006
3961	Feb. 4	Feb. 5	Slight.	Slight.	0.55	5.85	1.55	4.30	.0050	.0240 .0202	.58	.0400	.0007
4204	Mar. 4	Mar. 5	Slight.	Considerable, light.	0.25	4.20	1.20	3.00	.0020	.0248 .0142	.40	.0280	.0004
4447	Apr. 1	Apr. 2	Slight.	Very slight.	0.16	4.55	1.05	3.50	.0010	.0182 .0140	.48	.0120	.0008
4602	May 1	May 2	Slight.	Slight.	0.30	5.15	1.15	4.00	.0008	.0208 .0166	.57	.0200	.0004
Av.	....	....	....	....	0.65	5.10	1.63	3.47	.0047	.0262	.40	.0158	.0003

Hardness in May, 1888, 1.6. Odor, generally vegetable, occasionally disagreeable. —— The samples were collected from the pond, at the gate-house. Algæ appeared in the pond in June, 1887, and from June 2 to Aug. 24, 1887, no water was drawn from the pond for the supply of the city. During this time no water was diverted into the pond from the reservoirs. For monthly record of heights of water in this pond, see page 62.

Microscopical Examination.

	1888. June.	1888. July.	1888. Aug.	1888. Sept.	1888. Oct.	1888. Nov.	1888. Dec.	1889. Jan.	1889. Feb.	1889. Mar.	1889. Apr.	1889. May.
1. Blue-green Algæ, ...	pr.	0.0	4.0	pr.	pr.	0.0	0.0	0.0	0.0	0.0	0.0	pr.
2. Other Algæ, ...	5.0	0.5	7.0	8.0	0.7	pr.	0.0	1.4	0.4	0.0	4.3	1.1
3. Fungi, ...	0.0	0.1	0.0	pr.	0.0	0.0	0.0	0.0	0.0	0.0	0.0	pr.
4. Animal Forms, ...	pr.	0.1	pr.	0.6	0.3	0.0	0.0	0.0	2.4	450.8	3.2	0.0

Groups and principal genera of organisms observed: 1. Cyanophyceæ, *Anabæna*. 2. Palmellaceæ, *Chlorococcus*; Zoosporeæ; Desmidiaceæ; Diatomaceæ, *Asterionella*, *Stephanodiscus*, *Synedra*; Zygnemaceæ. 3. Schizomycetes. 4. Protozoa, *Dinobryon*, *Trachelomonas*; Annelida; Rotifera; Bryozoa; Entomostraca.

COCHITUATE SUPPLY. — *Chemical Examination of Water from Beaver Dam Brook at point of discharge into Lake Cochituate, in Natick.*

[Parts per 100,000.]

Number.	Date of Collection.	Date of Examination.	Appearance. Turbidity.	Appearance. Sediment.	Appearance. Color.	Residue on Evaporation. Total.	Residue on Evaporation. Loss on Ignition.	Residue on Evaporation. Fixed.	Ammonia. Free.	Ammonia. Albuminoid.	Chlorine.	Nitrogen as Nitrates.	Nitrogen as Nitrites.
	1887.												
23	May 31	June 2	Slight, milky.	Considerable.	1.00	8.25	3.48	4.77	.0098	.0447	0.35	.0260	–
230	June 30	July 1	Slight.	Slight.	0.85	8.00	1.80	6.20	.0044	.0304	.56	.0130	–
454	Aug. 1	Aug. 2	Very slight.	Slight.	0.60	8.25	1.35	6.90	.0014	.0256	0.72	.0260	–
668	Aug. 31	Sept. 1	Slight.	Considerable.	0.50	8.67	2.07	6.60	.0044	.0366	0.53	.0370	–
871	Oct. 3	Oct. 4	Decided.	Slight.	0.40	10.95	1.72	9.23	.0081	.0228	1.24	.0650	–
1080	Oct. 31	Nov. 1	Very slight.	Slight, earthy.	0.50	10.50 10.15	1.60 1.25	8.90 8.90	.0074	.0304 .0234	0.77	.0300	–
1291	Nov. 30	Dec. 1	Very slight.	Slight.	1.00	10.60	3.40	7.20	.0185	.0341	0.53	.0280	–
	1888.												
1521	Jan. 2	Jan. 3	Decided.	Much, earthy.	1.00	11.45 6.75	3.40 2.45	8.05 4.30	.0114	.0550 .0368	0.26	.0280	.0005
1727	Feb. 1	Feb. 2	Very slight.	Slight.	0.50	8.50	2.50	6.00	.0184	.0275	0.51	.0280	.0005
1936	Mar. 1	Mar. 2	Very slight.	Considerable.	0.70	6.50	1.95	4.55	.0129	.0295	0.31	.0180	.0002
2144	Apr. 2	Apr. 3	Decided.	Much, earthy.	1.00	6.30	2.20	4.10	.0139	.0412	0.33	.0100	.0008
2338	May 1	May 2	Slight.	Considerable.	1.40	7.55	2.40	5.15	.0130	.0388	0.39	.0090	.0007
2542	June 4	June 4	Very slight.	Slight, earthy.	1.10	7.45	2.75	4.70	.0032	.0354 .0346	0.32	.0200	.0015
2698	July 2	July 3	Distinct.	Slight.	0.70	7.95	2.55	5.40	.0068	.0280 .0262	0.57	.0400	.0021
2874	Aug. 1	Aug. 3	Slight.	Very slight.	0.40	7.90	1.80	6.10	.0068	.0244 .0224	0.92	.0500	.0008
	1888.												
3050	Sept. 4	Sept. 5	Distinct.	Slight.	0.60	8.40	2.30	6.10	.0022	.0328 .0292	.59	.0180	.0002
3296	Oct. 1	Oct. 2	Slight.	Very slight.	1.90	8.30	3.15	5.15	.0032	.0476 .0402	.38	.0150	.0005
3480	Oct. 31	Nov. 1	Decided.	Slight, earthy.	1.70	7.40	2.55	4.85	.0064	.0342 .0282	.44	.0200	.0005
3638	Dec. 3	Dec. 4	Very slight.	Slight, earthy.	0.80	6.45	2.60	3.85	.0126	.0270 .0210	.55	.0450	.0008
	1889.												
3808	Jan. 1	Jan. 2	Very slight.	Considerable, earthy.	0.80	6.00	1.90	4.10	.0110	.0222 .0200	.51	.0300	.0010
3962	Feb. 4	Feb. 5	Slight.	Considerable, earthy.	0.75	6.45	1.75	4.70	.0132	.0196 .0182	.47	.0480	.0006
4205	Mar. 4	Mar. 5	Decided.	Heavy, earthy.	0.55	6.45	1.90	4.55	.0104	.0210 .0162	.56	.0600	.0005
4448	Apr. 1	Apr. 2	Very slight.	Considerable, earthy.	0.80	5.85	2.10	3.75	.0134	.0246 .0218	.45	.0280	.0005
4603	May 1	May 2	Slight.	Slight.	1.20	6.85	2.60	4.25	.0038	.0372 .0312	.41	.0150	.0005
Av.	....	....	....	....	0.86	8.79	2.32	6.47	.0088	.0321	.53	.0295	.0007

Hardness in May, 1888, 3.0. Odor, generally vegetable and mouldy. —— The samples were collected from the brook at Mill Street, a short distance above Lake Cochituate.

Microscopical Examination.

	1888. June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.	1889. Jan.	Feb.	Mar.	Apr.	May.
1. Blue-green Algæ, ...	0.0	0.0	0.0	pr.	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
2. Other Algæ, ...	2.1	0.9	2.2	3.0	0.5	0.0	pr.	1.4	0.6	0.4	1.3	0.7
3. Fungi, ...	1.5	1.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
4. Animal Forms, ...	0.0	pr.	pr.	pr.	0.1	0.0	0.0	pr.	0.0	0.0	0.2	0.1

Groups and principal genera of organisms observed: 1. Cyanophyceæ. 2. Palmellaceæ; Zoosporeæ; Desmidiaceæ; Diatomaceæ, *Cocconeis*, *Melosira*, *Stauroneis*, *Synedra*. 3. Schizomycetes, *Crenothrix*, *Leptothrix*. 4. Protozoa; Spongilaria.

COCHITUATE SUPPLY. — *Chemical Examination of Water from Dudley Pond, in Wayland.*

[Parts per 100,000.]

Number.	Date of: Collection.	Date of: Examination.	Appearance: Turbidity.	Appearance: Sediment.	Appearance: Color.	Residue on Evaporation: Total.	Residue on Evaporation: Loss on Ignition.	Residue on Evaporation: Fixed.	Ammonia: Free.	Ammonia: Albuminoid.	Chlorine.	Nitrogen as: Nitrates.	Nitrogen as: Nitrites.
	1889.	1889.											
4208	Mar. 4	Mar. 5	Very slight.	Very slight.	0.10	2.60	0.95	1.65	.0062	.0198 .0182	.24	.0150	.0000
4451	Apr. 1	Apr. 2	Very slight.	Very slight.	0.10	2.85	0.75	2.10	.0082	.0220 .0184	.21	.0090	.0001
4605	May 1	May 2	Very slight.	Slight.	0.20	2.75	0.75	2.00	.0034	.0208 .0176	.22	.0050	.0002
Av.	....	....	....	....	0.13	2.73	0.82	1.91	.0059	.0209 .0181	.22	.0097	.0001

Hardness in March, 1.6. Odor, faintly vegetable. —— The samples were collected from the pond near the surface.

Microscopical Examination.

	1889. March.	1889. April.	1889. May.
1. Blue-green Algæ,	0.0	0.0	0.0
2. Other Algæ,	0.4	9.1	0.3
3. Fungi,	0.0	0.0	0.0
4. Animal Forms,	2.8	4.0	0.0

Groups and principal genera of organisms observed: 2. Palmellaceæ; Diatomaceæ, *Asterionella, Melosira, Stephanodiscus, Synedra, Tabellaria.* 4. Protozoa, *Dinobryon.*

COCHITUATE SUPPLY.—*Chemical Examination of Water from Lake Cochituate, in Wayland.*

[Parts per 100,000.]

Number.	Date of Collection.	Date of Examination.	Appearance. Turbidity.	Appearance. Sediment.	Appearance. Color.	Residue on Evaporation. Total.	Residue on Evaporation. Loss on Ignition.	Residue on Evaporation. Fixed.	Ammonia. Free.	Ammonia. Albuminoid.	Chlorine.	Nitrogen as Nitrates.	Nitrogen as Nitrites.
	1887.												
22	May 31	June 2	Distinct.	Very slight.	0.30	5.28	2.43	2.85	.0018	.0161	.42	.0130	-
233	June 30	July 1	Slight.	Slight.	0.20	4.70	0.85	3.85	.0027	.0193	.43	.0130	-
463	Aug. 1	Aug. 2	Very slight.	None.	0.30	4.92	1.45	3.47	.0012	.0147	.39	.0070	-
670	Aug. 31	Sept. 1	Very slight.	None.	0.15	5.02	1.32	3.70	.0002	.0184	.44	.0070	-
872	Oct. 3	Oct. 4	Very slight.	None.	0.10	5.10	1.10	4.00	.0005	.0190	.47	.0070	-
1081	Oct. 31	Nov. 1	Very slight.	Considerable.	0.20	5.25	1.00	4.25	.0024	.0206	.49	.0100	-
1292	Nov. 30	Dec. 1	Slight.	Considerable.	0.20	5.30	1.50	3.80	.0033	.0220	.42	.0100	-
	1888.												
1523	Jan. 2	Jan. 3	Slight.	Sli't, green.	0.20	4.95	1.25	3.70	.0015	.0197	.40	.0090	.0001
1729	Feb. 1	Feb. 2	Slight.	Slight.	0.15	5.40	1.25	4.15	.0041	.0186	.42	.0200	.0000
1937	Mar. 1	Mar. 2	Slight.	Very slight.	0.30	5.45	1.20	4.25	.0049	.0200	.48	.0180	.0001
2145	Apr. 2	Apr. 3	Slight.	Sli't, white.	0.20	5.05	1.10	3.95	.0016	.0197	.43	.0180	.0001
2339	May 1	May 2	Decided.	Consid'ble.	0.30	4.80	1.35	3.45	.0010	.0256	.40	.0120	.0003
2556	June 6	June 7	Slight.	Slight, white.	0.35	4.78	1.18	3.60	.0030	.0254 .0176	.40	.0200	.0004
2716	July 5	July 6	Distinct.	Very slight.	0.10	3.05	1.00	2.05	.0034	.0232 .0192	.42	.0180	.0004
2872	Aug. 1	Aug. 3	Very slight.	Slight.	0.10	5.20	1.25	3.95	.0008	.0234 .0196	.44	.0020	.0003
3051	Sept. 4	Sept. 5	Very slight.	Very slight, white.	0.05	4.90	1.05	3.85	.0012	.0230 .0186	.41	.0000	.0091
3297	Oct. 1	Oct. 2	Slight.	Slight, white.	0.05	4.70	1.25	3.45	.0004	.0200 .0166	.42	.0050	.0002
3481	Oct. 31	Nov. 1	Slight.	Slight.	0.25	4.90	1.50	3.40	.0098	.0200 .0162	.43	.0120	.0004
3639	Dec. 3	Dec. 4	Very slight.	Very slight.	0.20	5.60	1.55	4.05	.0074	.0212 .0182	.46	.0180	.0007
	1889.												
3809	Jan. 1	Jan. 2	Very slight.	Slight.	0.50	5.40	1.60	3.80	.0042	.0208 .0178	.46	.0250	.0006
3963	Feb. 4	Feb. 5	Slight, milky.	Slight.	0.45	5.35	2.00	3.35	.0050	.0212 .0178	.44	.0250	.0003
4206	Mar. 4	Mar. 5	Slight.	Con., light green.	0.50	5.10	1.70	3.40	.0002	.0210 .0182	.48	.0300	.0002
4449	Apr. 1	Apr. 2	Very slight.	Con., light green.	0.35	5.05	1.60	3.45	.0012	.0218 .0172	.46	.0300	.0002
4604	May 1	May 2	Very slight.	Slight.	0.45	4.50	1.20	3.30	.0014	.0212 .0184	.46	.0250	.0003
Av.	....	....	....	....	0.25	5.09	1.22	3.87	.0026	.0207	.44	.0148	.0003

Hardness in May, 1888, 1.8. Odor, generally faintly vegetable.—The samples were collected in the gate-house. For monthly record of heights of water in this lake, see page 62.

Microscopical Examination.

	1888. June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.	1889. Jan.	Feb.	Mar.	Apr.	May.
1. Blue-green Algæ,	0.4	0.1	0.1	0.1	pr.	pr.	0.0	0.0	0.0	0.0	0.0	pr.
2. Other Algæ,	8.9	0.4	4.4	2.6	2.0	10.7	7.5	16.1	17.2	28.9	18.1	52.4
3. Fungi,	0.0	pr.	0.0	0.0	pr.	0.0	0.4	0.1	0.0	0.0	0.0	0.0
4. Animal Forms,	pr.	pr.	pr.	pr.	0.2	0.2	pr.	0.2	0.9	1.0	1.9	2.1

Groups and principal genera of organisms observed: 1. Cyanophyceæ. 2. Palmellaceæ, *Chlorococcus;* Zoosporeæ, *Synedra;* Desmidiaceæ; Diatomaceæ, *Asterionella, Melosira, Stephanodiscus, Synedra, Tabellaria.* 3. Schizomycetes. 4. Protozoa, *Dinobryon;* Spongiaria; Rotifera; Entomostraca.

COCHITUATE WORKS. — *Chemical Examination of Water from Chestnut Hill Distributing Reservoir.*

[Parts per 100,000.]

Number.	Date of Collection.	Date of Examination.	Appearance: Turbidity.	Appearance: Sediment.	Appearance: Color.	Residue on Evaporation: Total.	Residue on Evaporation: Loss on Ignition.	Residue on Evaporation: Fixed.	Ammonia: Free.	Ammonia: Albuminoid.	Chlorine.	Nitrogen as Nitrates.	Nitrogen as Nitrites.
	1887.												
36	June 3	June 4	Very slight.	Very slight.	0.20	5.27	1.97	3.30	.0052	.0170	.37	.0320	-
241	July 1	July 1	Slight.	None.	0.55	5.57	1.27	4.30	.0019	.0202	.41	.0330	-
449	Aug. 1	Aug. 1	Very slight.	Slight.	0.40	4.72	0.90	3.82	.0027	.0169	.36	.0090	-
666	Sept. 1	Sept. 1	Slight.	Slight.	0.40	4.92	1.25	3.67	.0010	.0221	.40	.0070	-
881	Oct. 4	Oct. 4	Very slight.	Slight.	0.40	5.07	1.42	3.65	.0039	.0239	.45	.0100	-
1088	Nov. 2	Nov. 2	Slight.	Consid'ble.	0.40	5.05	1.50	3.55	.0002	.0300	.42	.0050	-
1306	Dec. 2	Dec. 2	Distinct.	Slight.	0.30	4.80	1.45	3.35	.0004	.0347	.35	.0040	-
	1888.												
1511	Jan. 2	Jan. 3	Very slight.	Slight.	0.70	5.10	1.45	3.65	.0018	.0278	.38	.0080	.0000
1709	Feb. 1	Feb. 1	Very slight.	Very slight.	0.70	5.30	1.80	3.50	.0030	.0226	.35	.0180	.0000
1924	Mar. 1	Mar. 1	Very slight.	Slight, white.	0.50	5.50	1.60	3.90	.0050	.0260	.48	.0250	.0001
2132	Apr. 2	Apr. 2	Distinct.	Slight, white.	0.35	4.85	1.25	3.60	.0016	.0212	.42	.0230	.0003
2345	May 2	May 2	Slight.	Con., green.	0.30	4.85	1.25	3.60	.0004	.0244	.41	.0250	.0004
2624	June 19	June 19	Very slight.	Slight, white.	0.40	4.55	1.15	3.40	.0038	.0196 .0162	.43	.0250	.0001
2742	July 9	July 9	Distinct.	Very slight.	0.40	4.55	1.25	3.30	.0002	.0226 .0188	.41	.0150	.0003
2884	Aug. 3	Aug. 4	Slight.	Slight, green.	0.20	4.90	1.20	3.70	.0002	.0204 .0180	.40	.0090	.0003
3072	Sept. 5	Sept. 6	Slight.	Very slight.	0.30	4.60	1.35	3.25	.0014	.0226 .0190	.37	.0150	.0002
3303	Oct. 2	Oct. 2	Slight.	Slight, green.	0.20	4.60	1.35	3.25	.0044	.0208 .0162	.35	.0120	.0003
3491	Nov. 1	Nov. 2	Very slight.	Very slight.	0.30	5.05	1.65	3.40	.0000	.0196 .0196	.40	.0200	.0002
3649	Dec. 4	Dec. 5	Very slight.	Very slight.	0.25	5.10	1.50	3.60	.0028	.0222 .0198	.45	.0350	.0004
	1889.												
3816	Jan. 2	Jan. 2	Very slight.	Very slight.	0.45	4.55	0.75	3.80	.0006	.0182 .0162	.48	.0280	.0003
3970	Feb. 5	Feb. 5	Very slight.	Very slight.	0.40	5.25	1.65	3.60	.0006	.0246 .0220	.44	.0400	.0003
4222	Mar. 5	Mar. 6	Very slight.	Very slight.	0.30	4.25	1.35	2.90	.0020	.0186 .0140	.40	.0280	.0002
4463	Apr. 2	Apr. 3	very Slight.	Slight.	0.45	4.55	1.80	2.75	.0016	.0192 .0170	.40	.0300	.0001
4612	May 3	May 3	~~Very~~ slight.	Very slight.	0.35	4.50	1.30	3.20	.0000	.0164 .0142	.41	.0250	.0003
Av.	....	....	....	....	0.38	5.08	1.43	3.65	.0019	.0222	.40	.0200	.0002

Hardness in May, 1888, 2.1. Odor, generally vegetable, seldom disagreeable. — The samples were collected from the effluent gate-house.

Microscopical Examination.

	1888. June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.	1889. Jan.	Feb.	Mar.	Apr.	May.
1. Blue-green Algæ,	0.0	0.1	pr.	pr.	pr.	0.0	0.0	0.0	0.0	0.0	0.0	0.0
2. Other Algæ,	3.5	4.2	2.6	0.7	0.3	6.6	2.5	10.1	0.2	6.2	2.2	13.2
3. Fungi,	0.0	0.0	0.0	0.0	0.0	0.1	0.4	0.0	0.0	0.0	0.0	0.0
4. Animals,	pr.	0.2	pr.	0.1	pr.	0.1	0.0	pr.	0.0	0.9	0.6	0.2

Groups and principal genera of organisms observed: 1. Cyanophyceæ. 2. Palmellaceæ, *Chlorococcus;* Zoosporeæ; Desmidiaceæ; Diatomaceæ, *Asterionella, Melosira, Stephanodiscus, Synedra, Tabellaria;* Zygnemaceæ. 3. Schizomycetes. 4. Protozoa; Spongiaria; Hydrozoa; Annelida; Rotifera; Bryozoa; Entomostraca.

COCHITUATE WORKS. — *Chemical Examination of Water from Brookline Distributing Reservoir.*

[Parts per 100,000.]

	Date of		Appearance.			Residue on Evaporation.			Ammonia.			Nitrogen as	
Number.	Collection.	Examination.	Turbidity.	Sediment.	Color.	Total.	Loss on Ignition.	Fixed.	Free.	Albuminoid.	Chlorine.	Nitrates.	Nitrites.
	1887.												
37	June 3	June 4	Very slight.	Very slight.	0.30	5.00	2.15	2.85	.0041	.0171	.42	.0190	–
240	July 1	July 1	Slight.	None.	0.60	5.20	1.15	4.05	.0025	.0242	.37	–	–
450	Aug. 1	Aug. 1	Very slight.	None.	0.40	4.95	0.90	4.05	.0034	.0166	.38	.0120	–
667	Sept. 1	Sept. 1	Slight.	Slight.	0.30	4.72	1.22	3.50	.0023	.0188	.40	.0070	–
880	Oct. 4	Oct. 4	Slight.	Slight.	0.45	5.20	1.37	3.83	.0025	.0263	.44	.0110	–
1087	Nov. 2	Nov. 2	Slight.	Slight, white.	0.40	4.80	1.35	3.45	.0002	.0293	.41	.0050	–
1307	Dec. 2	Dec. 2	Distinct.	Slight.	0.30	5.40	1.65	3.75	.0006	.0255	.39	.0080	–
	1888.												
1510	Jan. 2	Jan. 3	Slight.	Slight, white.	0.30	5.25	1.40	3.85	.0018	.0257	.41	.0090	.0000
1710	Feb. 1	Feb. 1	Very slight.	Very slight.	0.90	5.55	1.95	3.60	.0031	.0216	.37	.0280	.0000
1925	Mar. 1	Mar. 1	Very slight.	Slight.	0.50	5.80	1.75	4.05	.0065	.0225	.49	.0300	.0001
2131	Apr. 2	Apr. 2	Distinct.	Slight, white.	0.30	4.80	0.95	3.85	.0008	.0229	.40	.0300	.0003
2344	May 2	May 2	Distinct.	Slight, green.	0.30	4.65	1.50	3.15	.0012	.0224	.41	.0200	.0003
2623	June 19	June 19	Very slight.	Slight, white.	0.45	4.95	1.45	3.50	.0048	.0188 .0156	.43	.0250	.0001
2744	July 9	July 9	Slight.	Slight.	0.60	4.80	1.70	3.10	.0010	.0240 .0184	.39	.0100	.0002
2885	Aug. 3	Aug. 4	Slight.	Slight, green.	0.30	5.00	1.25	3.75	.0026	.0218 .0200	.42	.0070	.0002
3071	Sept. 5	Sept. 6	Slight.	Slight.	0.40	4.50	1.40	3.10	.0010	.0246 .0190	.35	.0100	.0002
	1888.												
3304	Oct. 2	Oct. 2	Slight.	Slight, green.	0.25	4.80	1.40	3.40	.0000	.0254 .0198	.37	.0150	.0003
3490	Nov. 1	Nov. 2	Distinct.	Slight.	0.40	5.25	1.55	3.70	.0002	.0280 .0190	.44	.0280	.0002
3650	Dec. 4	Dec. 5	Slight.	Very slight.	0.30	5.60	1.75	3.85	.0010	.0208 .0178	.48	.0350	.0004
	1889.												
3815	Jan. 2	Jan. 2	Very slight.	Slight.	0.50	4.35	0.80	3.55	.0006	.0186 .0164	.40	.0360	.0000
3969	Feb. 5	Feb. 5	Very slight.	Slight.	0.40	4.45	0.70	3.75	.0000	.0182 .0162	.41	.0380	.0004
4223	Mar. 5	Mar. 6	Very slight.	Slight.	0.35	4.55	1.40	3.15	.0002	.0168 .0138	.40	.0310	.0003
4461	Apr. 2	Apr. 3	Very slight.	Slight, green.	0.45	4.65	1.50	3.15	.0024	.0202 .0168	.37	.0200	.0002
4613	May 3	May 3	Slight.	Slight, white.	0.40	4.60	1.35	3.25	.0002	.0178 .0148	.40	.0250	.0003
Av.	....	....	....	....	0.43	5.11	1.45	3.66	.0018	.0220	.41	.0197	.0002

Hardness in May, 1888, 2.1. Odor, generally vegetable, seldom disagreeable. — The samples were collected from the effluent gate-house.

Microscopical Examination.

	1888.							1889.				
	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May.
1. Blue-green Algæ,	pr.	0.1	pr.	0.3	pr.	0.0	0.0	pr.	0.0	0.0	0.0	0.0
2. Other Algæ,	10.8	17.0	8.3	7.1	7.9	22.3	6.6	5.4	0.5	8.4	21.3	23.2
3. Fungi,	0.0	0.0	0.0	pr.	0.0	pr.	0.1	pr.	0.0	pr.	0.0	0.0
4. Animals,	pr.	0.2	0.0	0.5	pr.	0.1	0.0	0.1	pr.	5.0	0.4	4.3

Groups and principal genera of organisms observed: 1. Cyanophyceæ. 2. Palmellaceæ, *Chlorococcus;* Zoosporeæ, *Raphidium, Staurogenia;* Desmidiaceæ; Diatomaceæ, *Asterionella, Melosira, Stephanodiscus, Synedra, Tabellaria.* 3. Schizomycetes. 4. Protozoa, *Dinobryon;* Spongiaria; Rotifera; Entomostraca.

COCHITUATE WORKS. — *Chemical Examination of Water from Fisher Hill Distributing Reservoir.*

[Parts per 100,000.]

Number.	Date of Collection.	Date of Examination.	Appearance. Turbidity.	Appearance. Sediment.	Appearance. Color.	Residue on Evaporation. Total.	Residue on Evaporation. Loss on Ignition.	Residue on Evaporation. Fixed.	Ammonia. Free.	Ammonia. Albuminoid.	Chlorine.	Nitrogen as Nitrates.	Nitrogen as Nitrites.
	1888.												
2622	June 19	June 19	Very slight.	Slight.	0.20	4.80	1.20	3.60	.0018	.0226 .0158	.44	.0200	.0002
2743	July 9	July 9	Slight.	Slight.	0.40	4.70	1.75	2.95	.0000	.0232 .0166	.39	.0150	.0003
2883	Aug. 3	Aug. 4	Slight.	Slight.	0.20	5.05	1.50	3.55	.0012	.0238 .0192	.41	.0070	.0003
3073	Sept. 5	Sept. 6	Slight.	Slight, green.	0.25	4.70	1.40	3.30	.0002	.0226 .0216	.36	.0070	.0002
3302	Oct. 2	Oct. 2	Slight.	Slight, green.	0.20	4.55	1.15	3.40	.0008	.0228 .0214	.36	.0100	.0001
3492	Nov. 1	Nov. 2	Very slight.	Very slight.	0.20	5.15	1.10	4.05	.0000	.0228 .0194	.43	.0250	.0002
3648	Dec. 4	Dec. 5	Very slight.	Very slight.	0.25	5.20	1.75	3.45	.0018	.0194 .0194	.45	.0400	.0003
	1889.												
3814	Jan. 2	Jan. 2	Very slight.	Very slight.	0.45	4.70	0.45	4.25	.0020	.0222 .0196	.45	.0430	.0000
3971	Feb. 5	Feb. 5	Very slight.	Slight.	0.35	4.90	1.25	3.65	.0002	.0208 .0170	.42	.0250	.0004
4224	Mar. 5	Mar. 6	Very slight.	Very slight.	0.30	4.65	1.40	3.25	.0002	.0182 .0168	.43	.0210	.0002
4462	Apr. 2	Apr. 3	Very slight.	Very slight, green.	0.40	4.60	1.55	3.05	.0014	.0198 .0168	.39	.0400	.0001
4614	May 3	May 3	Slight.	Slight, white.	0.50	4.60	1.35	3.25	.0004	.0182 .0170	.41	.0250	.0002
Av.	....	....	....	....	0.31	4.80	1.32	3.48	.0008	.0214 .0186	.41	.0226	.0002

Odor very faintly vegetable. —— The samples were collected from the reservoir.

Microscopical Examination.

	1888. June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.	1889. Jan.	Feb.	Mar.	Apr.	May.
1. Blue-green Algæ, ...	0.3	pr.	pr.	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
2. Other Algæ, ...	21.4	20.8	2.4	1.3	0.6	2.4	7.0	9.7	0.7	82.0	64.7	10.5
3. Fungi, ...	0.0	0.0	0.0	0.0	0.0	pr.	pr.	0.1	pr.	0.0	0.0	0.0
4. Animals, ...	pr.	0.3	0.0	0.1	pr.	pr.	0.2	0.1	0.0	2.0	1.9	0.6

Groups and principal genera of organisms observed: 1. Cyanophyceæ. 2. Palmellaceæ, *Chlorococcus;* Zoosporeæ; Desmidiaceæ; Diatomaceæ; *Asterionella, Melosira, Stephanodiscus, Synedra, Tabellaria.* 3. Schizomycetes. 4. Protozoa, *Dinobryon;* Rotifera; Entomostraca.

COCHITUATE WORKS. — *Chemical Examination of Water from Parker Hill Distributing Reservoir.*

[parts per 100,000]

Number.	Date of Collection.	Date of Examination.	Appearance. Turbidity.	Appearance. Sediment.	Appearance. Color.	Residue on Evaporation. Total.	Residue on Evaporation. Loss on Ignition.	Residue on Evaporation. Fixed.	Ammonia. Free.	Ammonia. Albuminoid.	Chlorine.	Nitrogen as Nitrates.	Nitrogen as Nitrites.
	1887.												
35	June 3	June 4	Slight.	Slight.	0.20	4.87	2.20	2.67	.0020	.0167	–	.0190	–
244	July 1	July 2	Very slight.	Considerable.	0.50	4.97	1.55	3.42	.0009	.0248	.37	.0260	–
465	Aug. 1	Aug. 2	Very slight.	Very slight.	0.40	5.05	1.75	3.30	.0010	.0180	.35	.0120	–
672	Sept. 1	Sept. 1	Slight.	Slight.	0.25	4.97	1.50	3.47	.0003	.0217	.40	.0070	–
882	Oct. 4	Oct. 5	Very slight.	Very slight.	0.35	5.30	1.30	4.00	.0000	.0276	.45	.0070	–
1161	Nov. 12	Nov. 12	Slight.	Slight.	0.30	5.05	1.70	3.35	.0000	.0271	.41	.0040	–
1308	Dec. 2	Dec. 3	Distinct.	Considerable.	0.40	5.40	1.55	3.85	.0004	.0247	.36	.0040	–
	1888.												
1525	Jan. 2	Jan. 3	Slight.	Slight, white.	0.30	3.95	0.85	3.10	.0016	.0232	.38	.0070	.0001
1720	Feb. 1	Feb. 1	Slight.	Slight.	0.50	6.15	2.20	3.95	.0046	.0294	.46	.0090	.0000
1919	Mar. 1	Mar. 1	Slight.	Slight, white.	0.10	3.15	0.65	2.50	.0058	.0165	.30	.0070	.0001
2129	Apr. 2	Apr. 2	Slight.	Very slight.	0.35	4.45	1.20	3.25	.0029	.0263	.38	.0080	.0002
2342	May 2	May 2	Slight.	Slight.	0.20	4.75	1.20	3.55	.0000	.0266	.39	.0010	.0002
2631	June 18	June 20	Very slight.	Slight, white.	0.10	4.55	1.10	3.45	.0010	.0210 .0154	.44	.0020	.0001
2878	Aug. 2	Aug. 3	Distinct.	Slight.	0.30	5.15	1.45	3.70	.0028	.0216 .0196	.40	.0090	.0002
Av.	....	....	....	....	0.30	4.84	1.47	3.37	.0017	.0232	.39	.0087	.0001

Hardness in May, 1888, 1.9; in June, 1889, 1.9. Odor, generally vegetable, seldom disagreeable. —— The samples were collected from the reservoir at the gate-house. No water was run into or drawn from the reservoir between ~~the time of taking Nos. 1525 and 2631.~~ Dec. 3, 1887 and July 2, 1888

Microscopical Examination.

	1888. April.	1888. May.	1888. June.	1888. August.
1. Blue-green Algæ, ...	0.0	0.0	pr.	pr.
2. Other Algæ, ...	pr.	pr.	0.9	8.1
3. Fungi, ...	0.0	0.0	0.0	pr.
4. Animals, ...	pr.	pr.	0.0	0.1

Groups and principal genera of organisms observed: 1. Cyanophyceæ. 2. Palmellaceæ, *Chlorococcus;* Zoosporeæ; Desmidiaceæ; Diatomaceæ. 3. Schizomycetes. 4. Protozoa; Entomostraca.

COCHITUATE WORKS. — *Chemical Examination of Water from a Faucet at the Massachusetts Institute of Technology.*

[Parts per 100,000.]

Number.	Date of Collection.	Date of Examination.	Appearance. Turbidity.	Appearance. Sediment.	Appearance. Color.	Residue on Evaporation. Total.	Residue on Evaporation. Loss on Ignition.	Residue on Evaporation. Fixed.	Ammonia. Free.	Ammonia. Albuminoid.	Chlorine.	Nitrogen as Nitrates.	Nitrogen as Nitrites.
	1887.												
466	Aug. 2	Aug. 2	Very slight.	Slight.	0.50	5.00	1.75	3.25	.0000	.0172	.35	.0120	-
671	Sept. 1	Sept. 1	Slight.	Very slight.	0.30	4.90	1.32	3.58	.0004	.0185	.48	.0130	-
876	Oct. 4	Oct. 4	Very slight.	Slight.	0.25	5.02	1.22	3.80	.0000	.0231	.43	.0100	-
1083	Nov. 1	Nov. 1	Slight.	Slight.	0.35	4.77	1.47	3.30	.0004	.0252	.43	.0050	-
1297	Dec. 1	Dec. 1	Distinct.	Slight, white.	0.35	4.75	1.10	3.65	.0008	.0284	.37	.0070	-
	1888.												
1526	Jan. 3	Jan. 3	Distinct.	Slight, white.	0.50	5.00	1.50	3.50	.0018	.0270	.38	.0080	.0000
1721	Feb. 2	Feb. 2	Very slight.	Very slight.	0.70	5.30	1.95	3.35	.0031	.0223	.39	.0250	.0000
1921	Mar. 1	Mar. 1	Very slight.	Slight, earthy.	0.70	5.55	1.70	3.85	.0039	.0209	.49	.0250	.0002
2130	Apr. 2	Apr. 2	Slight.	None.	0.30	4.90	1.20	3.70	.0014	.0212	.40	.0250	.0002
2341	May 2	May 2	Slight.	Very slight.	0.30	4.60	1.50	3.10	.0012	.0218	.39	.0180	.0004
2647	June 22	June 22	Very slight.	Slight.	0.30	4.60	1.36	3.30	.0004	.0194 .0164	.40	.0180	.0001
2766	July 13	July 13	Distinct.	Slight, rusty.	0.45	4.85	1.80	3.05	.0020	.0248 .0218	.39	.0150	.0002
2862	Aug. 2	Aug. 2	Distinct.	Slight, brown.	0.40	4.90	1.15	3.75	.0002	.0240 .0214	.42	.0180	.0002
3056	Sept. 5	Sept. 5	Slight.	Slight.	0.20	4.60	1.35	3.25	.0000	.0180 .0180	.36	.0070	.0001
3288	Oct. 2	Oct. 2	Slight.	Slight.	0.20	4.60	1.50	3.10	.0004	.0234 .0194	.35	.0100	.0002
3484	Nov. 1	Nov. 1	Very slight.	Very slight.	0.30	5.15	1.65	3.50	.0000	.0182 .0162	.42	.0200	.0001
3642	Dec. 4	Dec. 4	Very slight.	Very slight.	0.25	5.25	1.70	3.55	.0000	.0172 .0136	.44	.0300	.0004
	1889.												
3812	Jan. 2	Jan. 2.	Slight.	Very slight.	0.40	4.80	1.55	3.25	.0006	.0172 .0162	.42	.0350	.0005
3965	Feb. 5	Feb. 5	Very slight.	Very slight.	0.35	4.90	0.90	4.00	.0000	.0184 .0152	.41	.0500	.0002
4211	Mar. 5	Mar. 5	Very slight.	Very slight.	0.45	4.70	1.75	2.95	.0004	.0176 .0156	.44	.0500	.0003
4459	Apr. 3	Apr. 3	Very slight.	Very slight.	0.45	4.55	1.45	3.10	.0010	.0150 .0150	.39	.0280	.0002
4611	May 3	May 3	Slight.	Slight.	0.40	4.60	1.50	3.10	.0006	.0174 .0154	.41	.0250	.0003
Av.	....	....	....	....	0.38	4.98	1.47	3.51	.0008	.0207	.41	.0206	.0002

Hardness in May, 1888, 1.9. Odor, generally vegetable, seldom disagreeable.

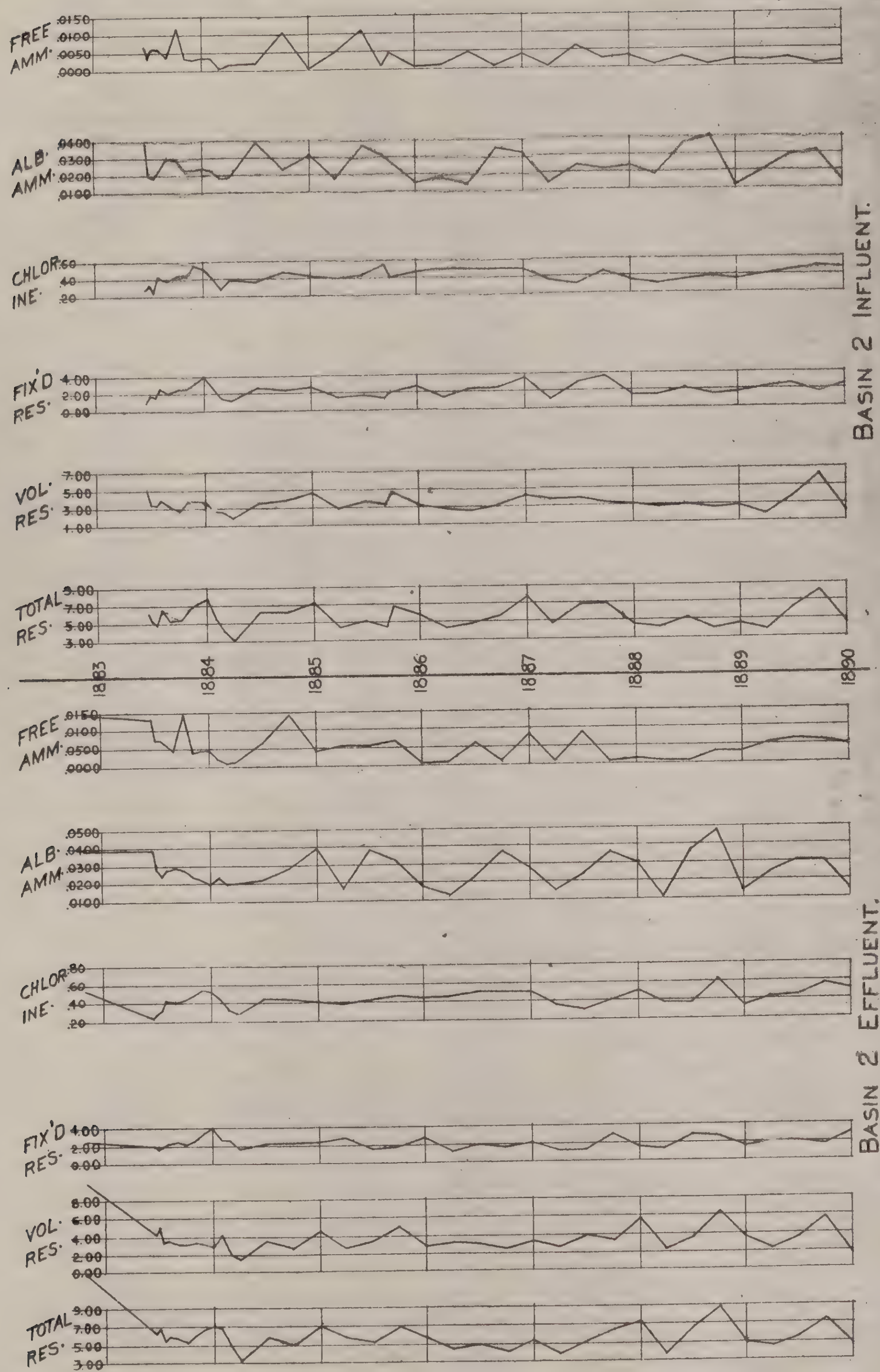
Microscopical Examination.

	1888. June.	1888. July.	1888. Aug.	1888. Sept.	1888. Oct.	1888. Nov.	1888. Dec.	1889. Jan.	1889. Feb.	1889. Mar.	1889. Apr.	1889. May.
1. Blue-green Algæ,	0.1	pr.	0.2	0.1	0.3	0.0	0.0	0.0	0.0	0.0	0.0	0.0
2. Other Algæ,	25.9	3.2	8.5	0.6	4.4	0.3	6.2	5.2	9.9	3.6	12.5	18.6
3. Fungi,	0.4	0.0	0.0	0.0	0.0	0.0	0.8	0.0	0.0	0.0	0.0	pr.
4. Animals,	1.4	0.1	0.2	0.1	0.3	11.2	0.1	pr.	0.0	0.2	0.7	0.5

Groups and principal genera of organisms observed: 1. Cyanophyceæ. 2. Palmellaceæ, *Chlorococcus;* Zoosporeæ; Desmidiaceæ; Diatomaceæ, *Asterionella, Melosira, Stephanodiscus, Synedra, Tabellaria.* 3. Schizomycetes. 4. Protozoa, *Dinobryon, Hydromorum;* Spongiaria.

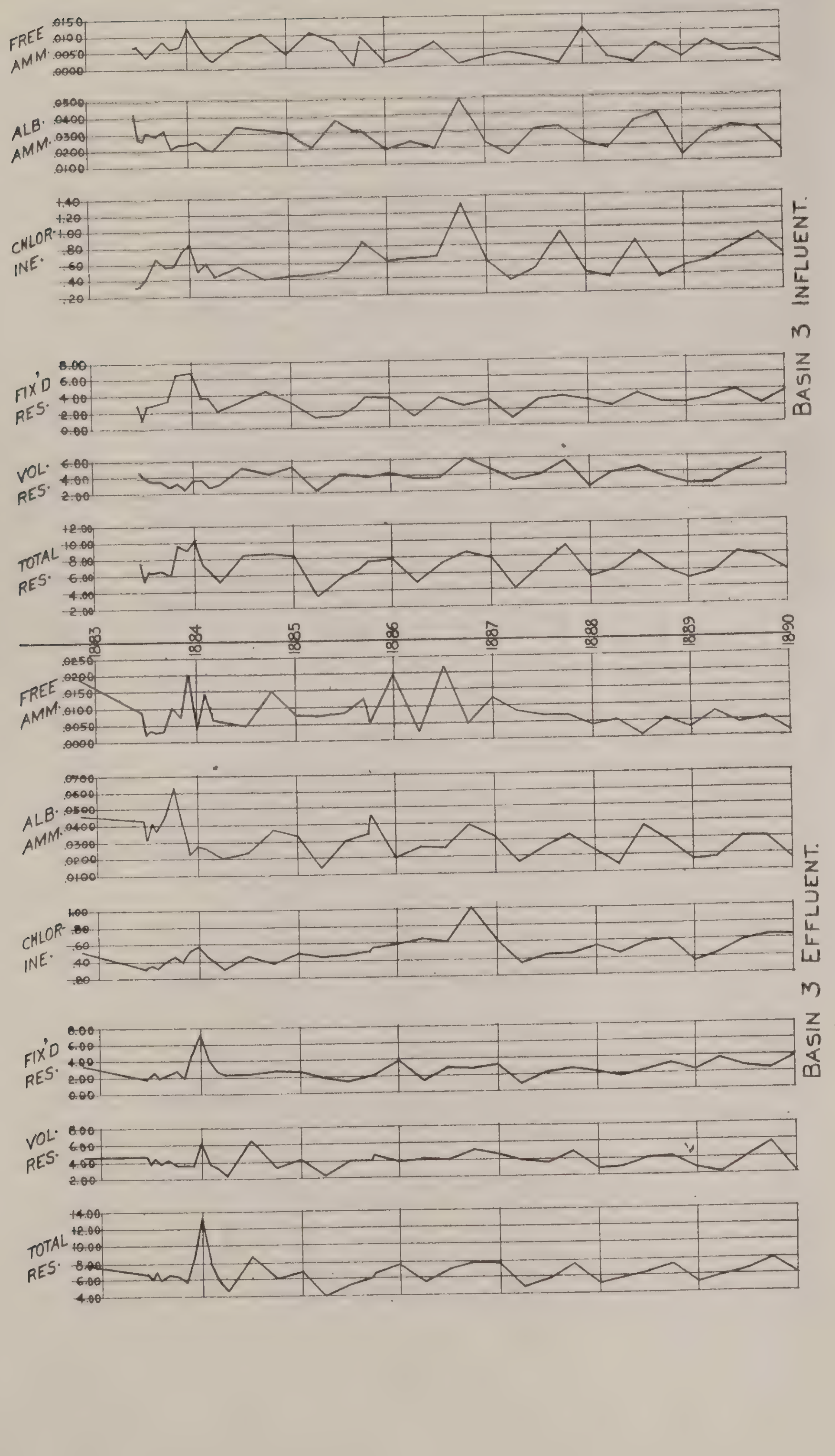
BASIN 2.

Plate 37

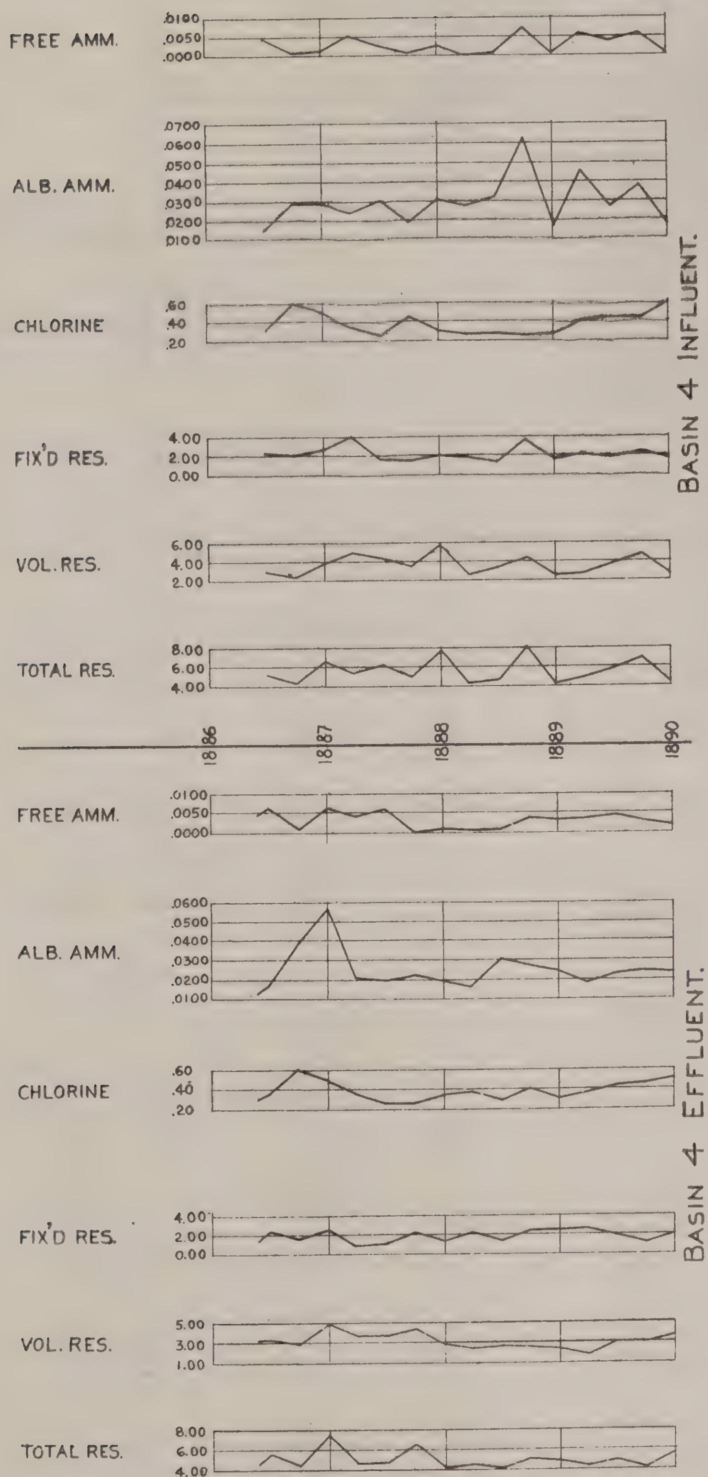


BASIN 3.

Plate 38.

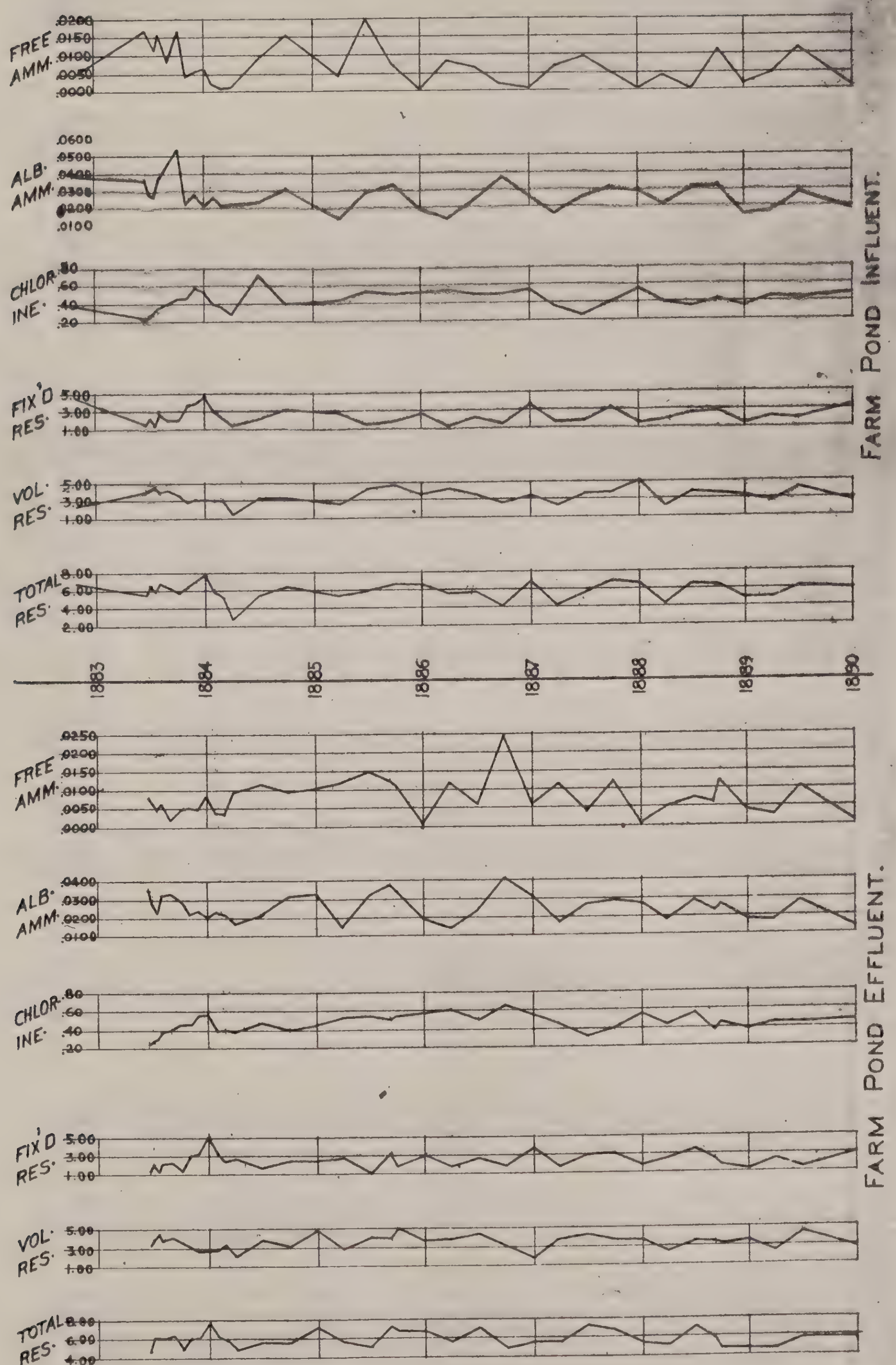


Basin 4. *Plate 39*



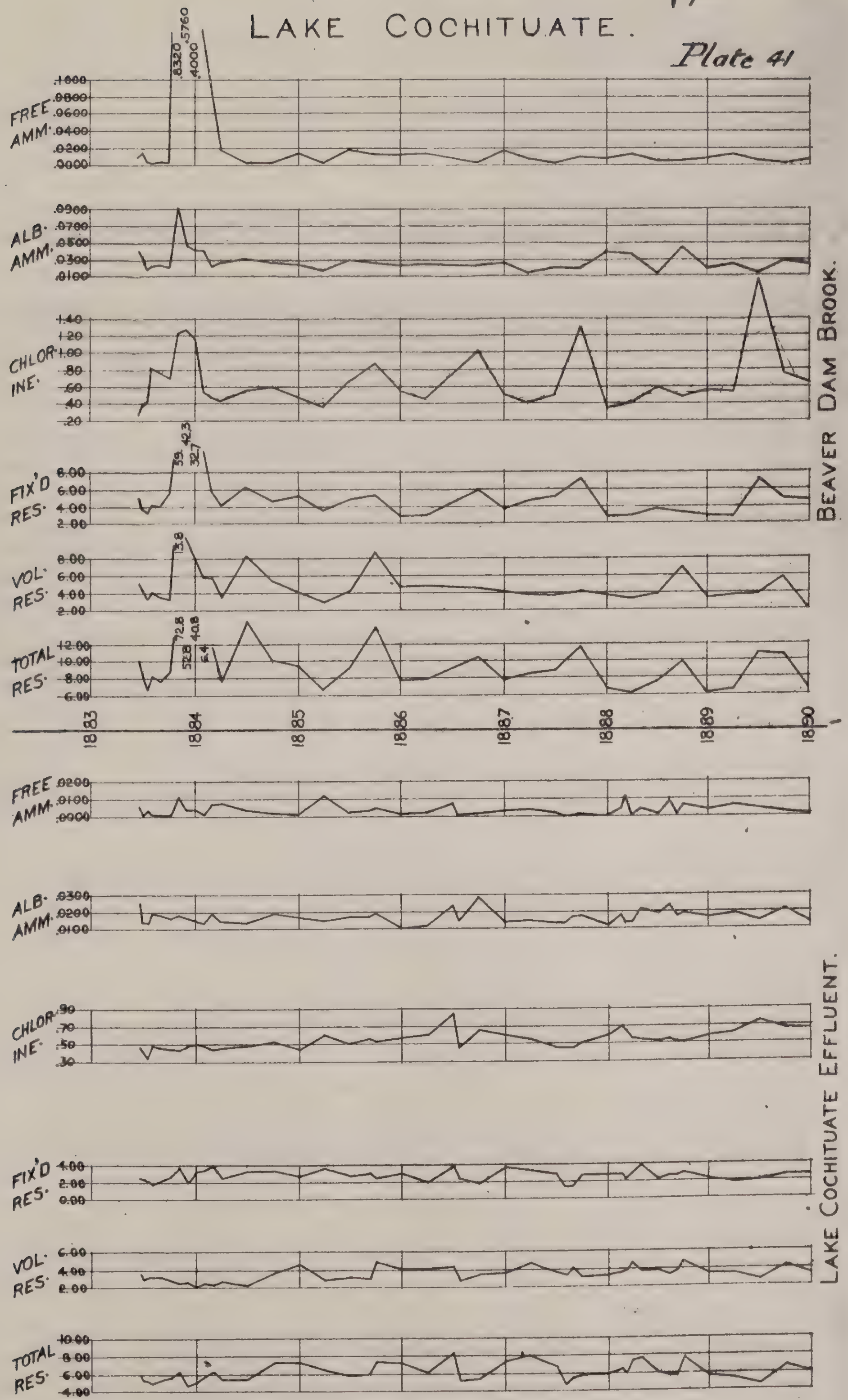
FARM POND.

Plate 40

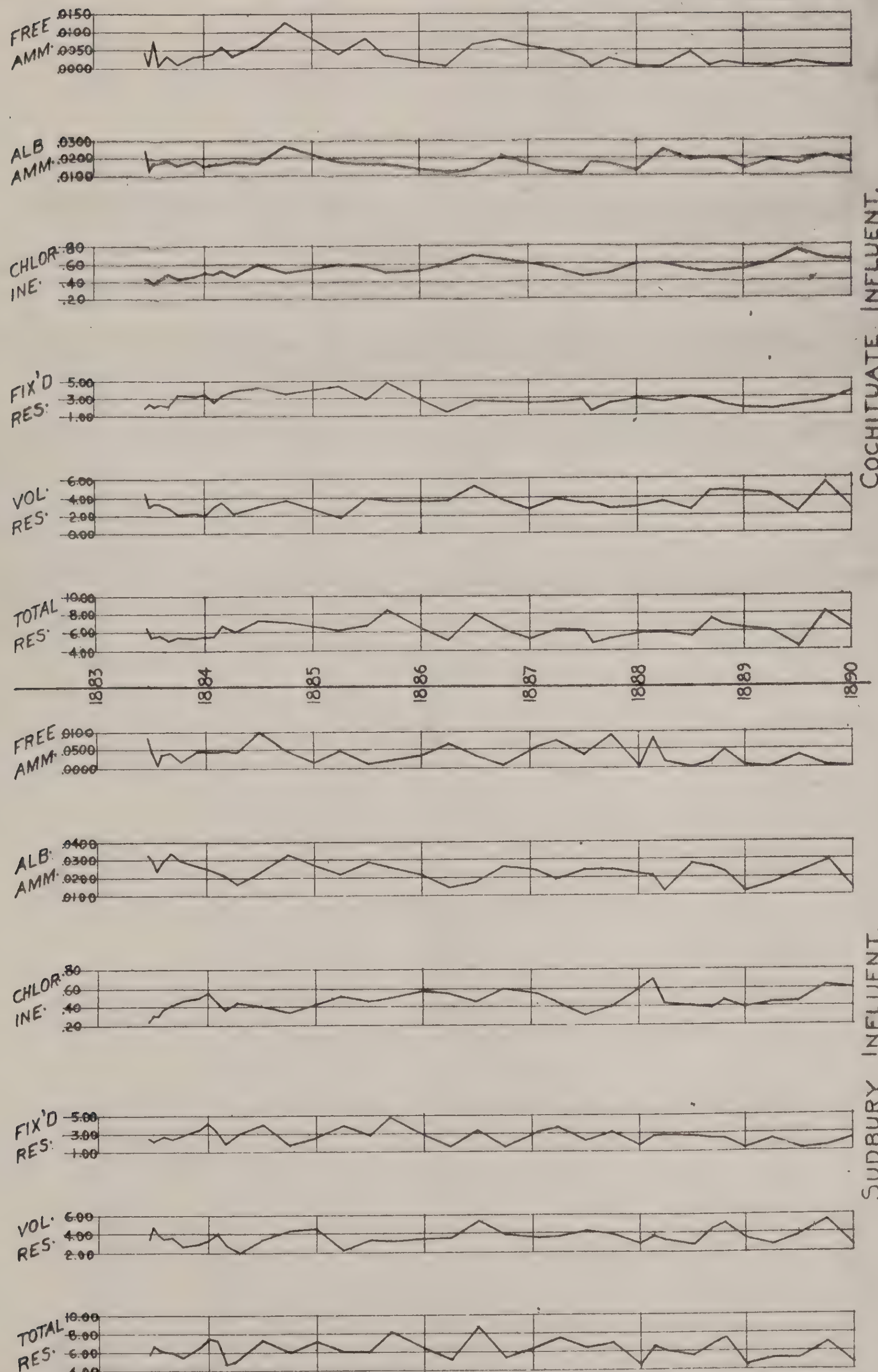


LAKE COCHITUATE.

Plate 41



CHESTNUT HILL RESERVOIR. *Plate 42*



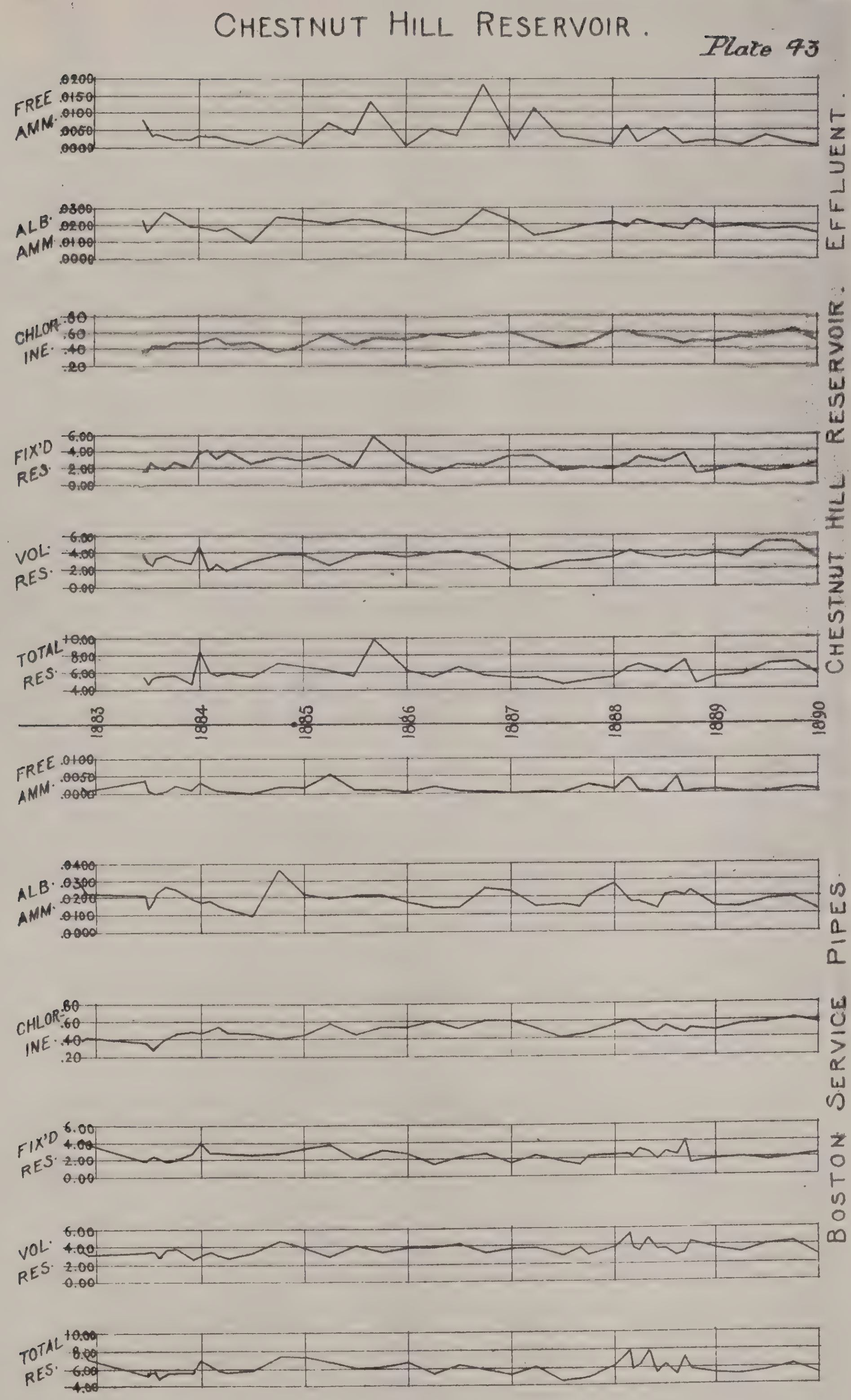

CHESTNUT HILL RESERVOIR.
Plate 43
CHESTNUT HILL RESERVOIR: EFFLUENT.
BOSTON SERVICE PIPES
FREE AMM.
ALB. AMM.
CHLORINE.
FIX'D RES.
VOL. RES.
TOTAL RES.
1883
1884
1885
1886
1887
1888
1889
1890

PLATE 44

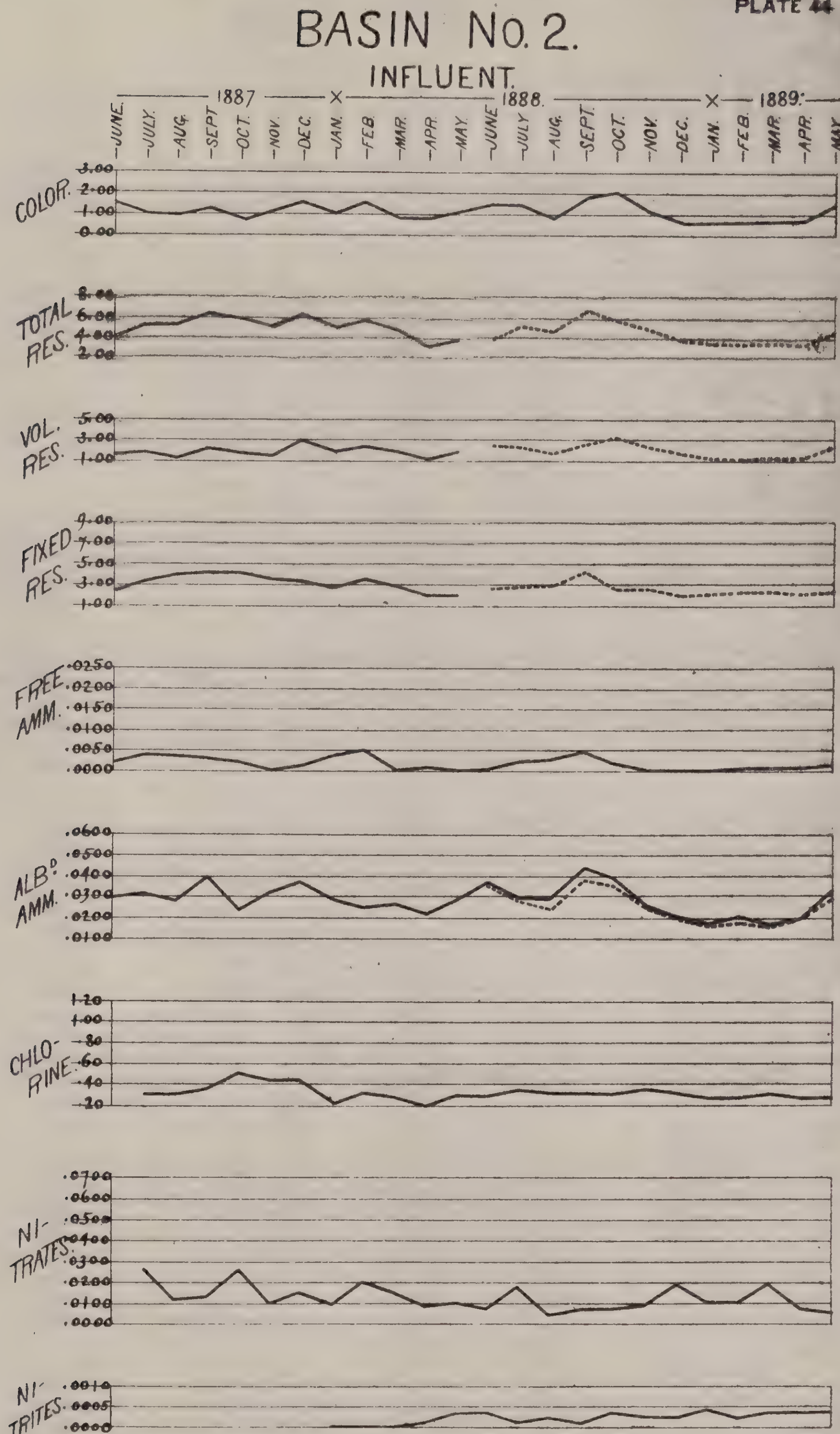

BASIN No. 2.
INFLUENT.
1887
1888.
1889.
JUNE. JULY. AUG. SEPT. OCT. NOV. DEC. JAN. FEB. MAR. APR. MAY. JUNE. JULY. AUG. SEPT. OCT. NOV. DEC. JAN. FEB. MAR. APR. MAY.
COLOR.
TOTAL RES.
VOL. RES.
FIXED RES.
FREE AMM.
ALB. AMM.
CHLORINE.
NITRATES.
NITRITES.

PLATE 45

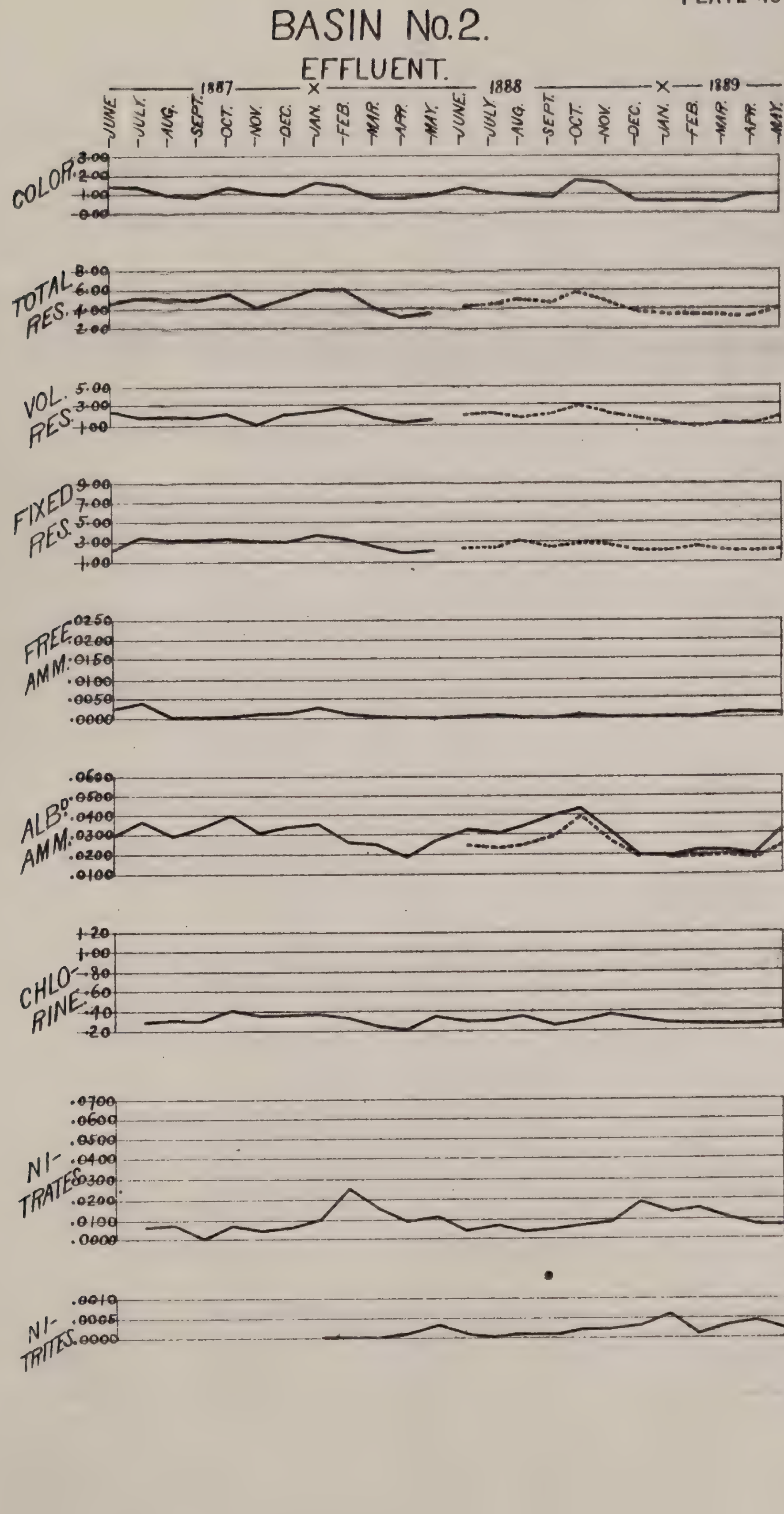

BASIN No.2.
EFFLUENT.
1887 × 1888 × 1889
JUNE JULY AUG. SEPT. OCT. NOV. DEC. JAN. FEB. MAR. APR. MAY. JUNE JULY AUG. SEPT. OCT. NOV. DEC. JAN. FEB. MAR. APR. MAY.
COLOR.
TOTAL RES.
VOL. RES.
FIXED RES.
FREE AMM.
ALB^D. AMM.
CHLORINE.
NITRATES.
NITRITES.

PLATE 46

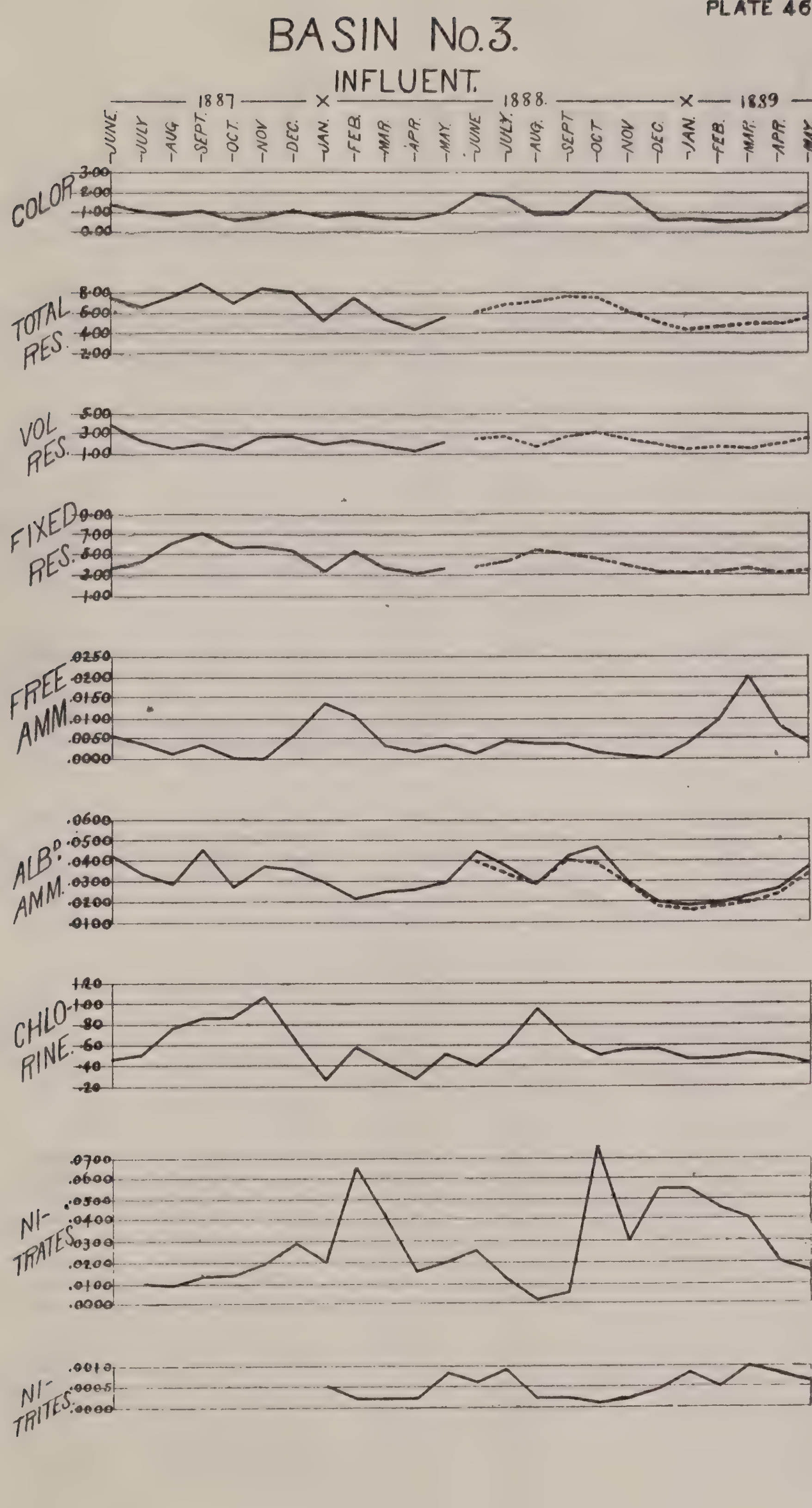

BASIN No. 3.
INFLUENT.
1887
1888.
1889
JUNE
JULY
AUG.
SEPT.
OCT.
NOV.
DEC.
JAN.
FEB.
MAR.
APR.
MAY.
COLOR
TOTAL RES.
VOL RES.
FIXED RES.
FREE AMM.
ALBD. AMM.
CHLORINE.
NITRATES.
NITRITES.

PLATE 47

BASIN No.3.

EFFLUENT.

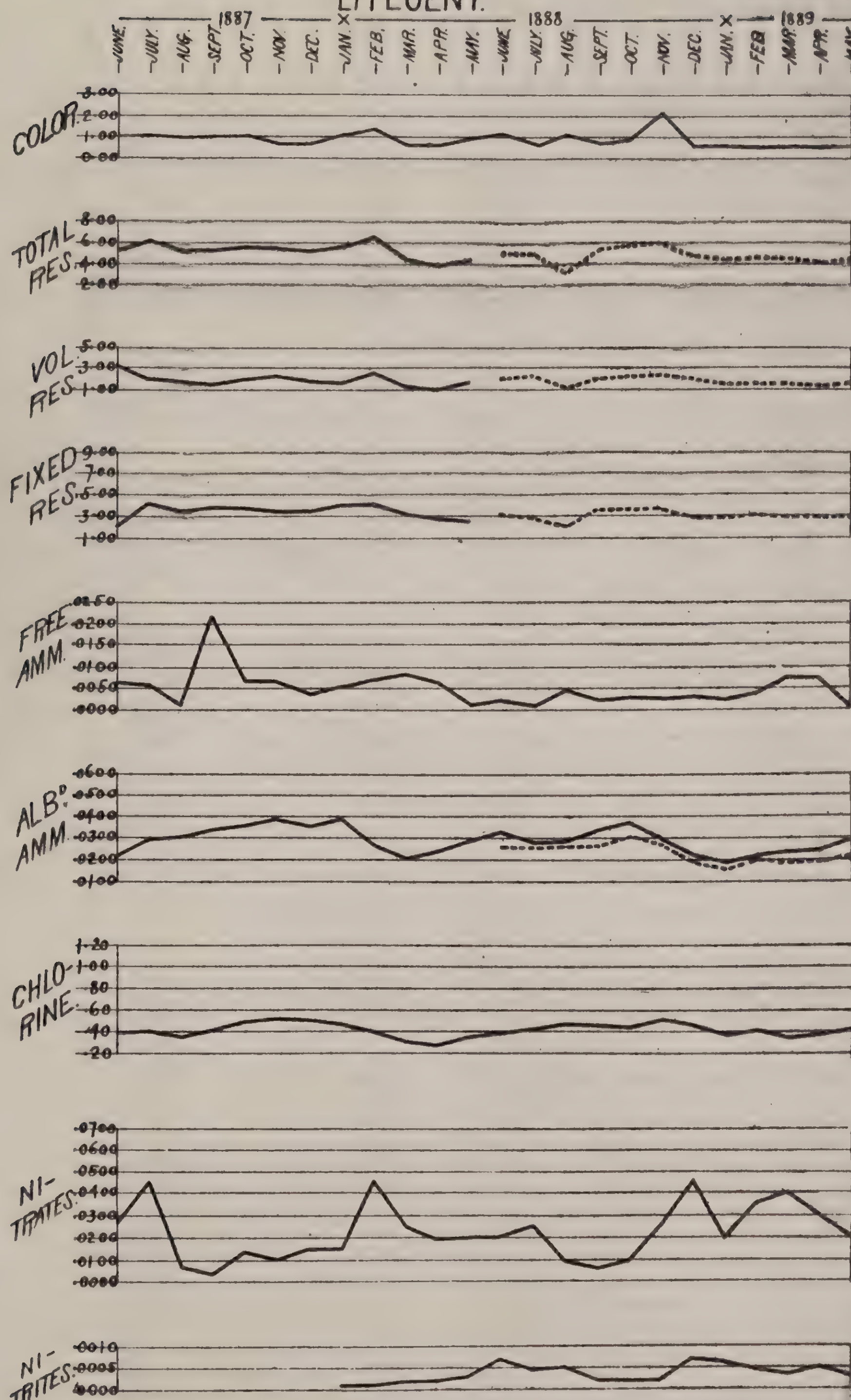


PLATE 48

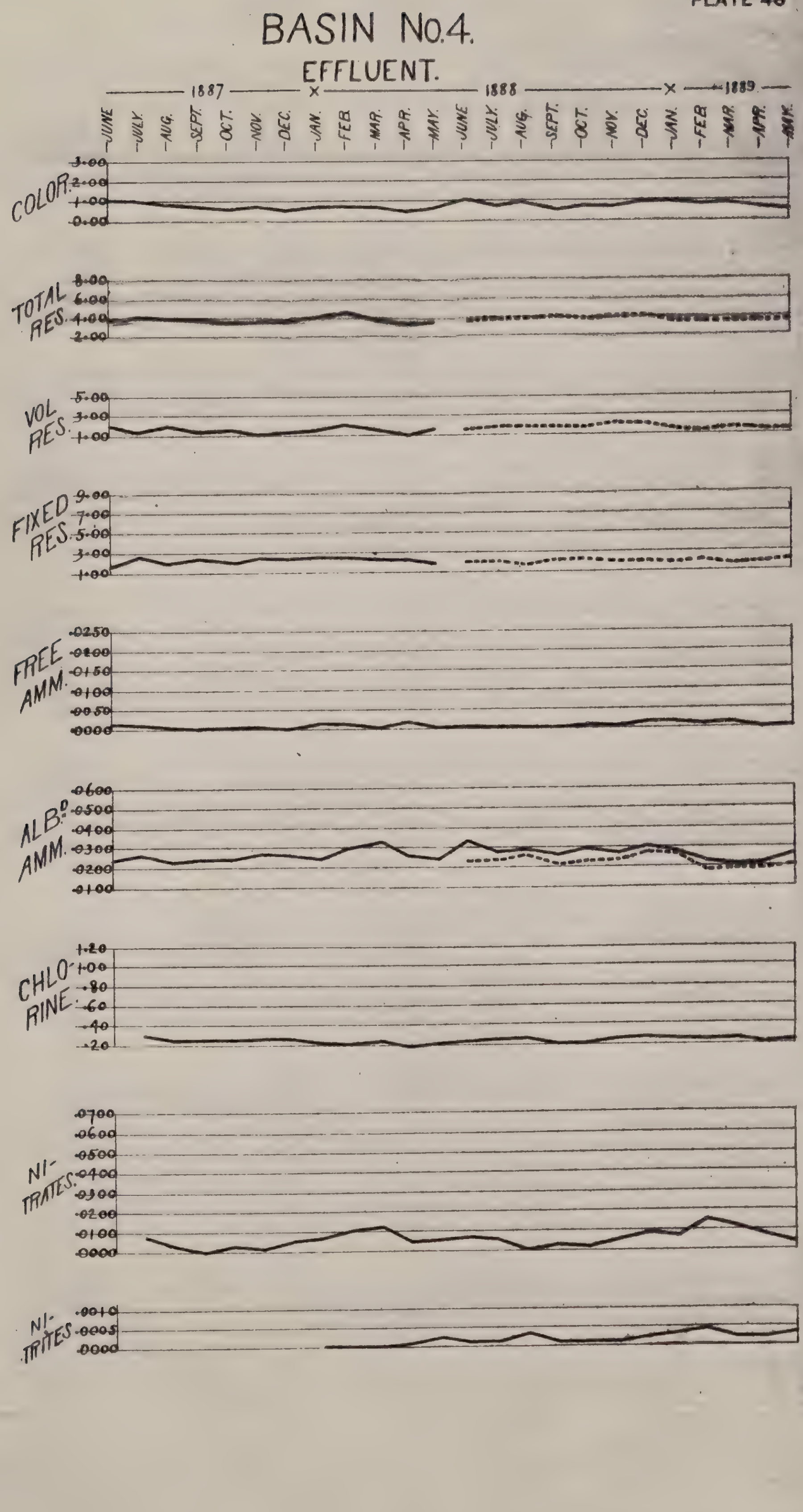

BASIN No.4.
EFFLUENT.
1887
1888
1889
JUNE
JULY
AUG.
SEPT.
OCT.
NOV.
DEC.
JAN.
FEB.
MAR.
APR.
MAY.
COLOR.
TOTAL RES.
VOL. RES.
FIXED RES.
FREE AMM.
ALB^D AMM.
CHLORINE.
NITRATES.
NITRITES.

PLATE 49

LAKE COCHITUATE.

INFLUENT.—BEAVER DAM BROOK.

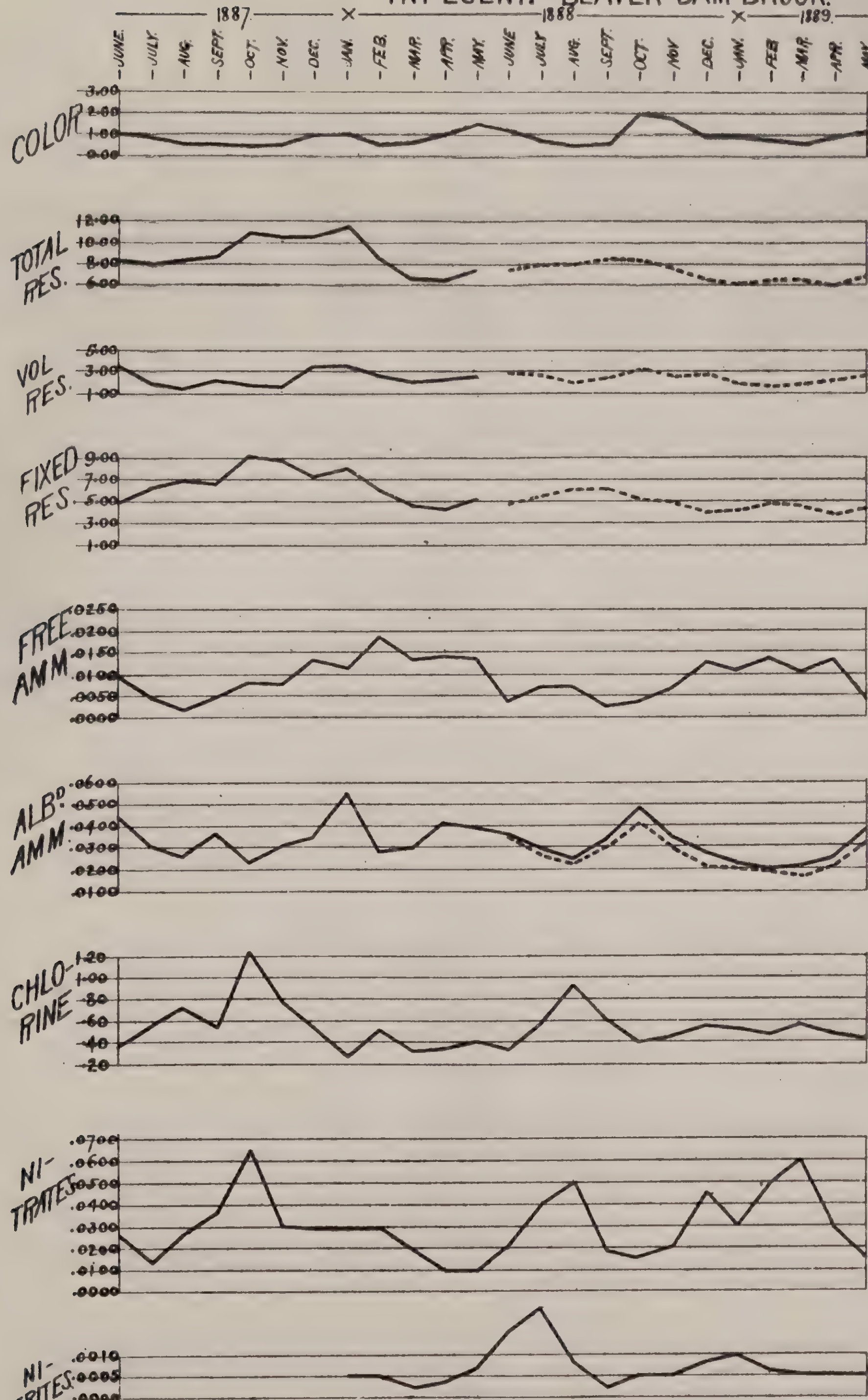


PLATE 50

LAKE COCHITUATE

EFFLUENT.

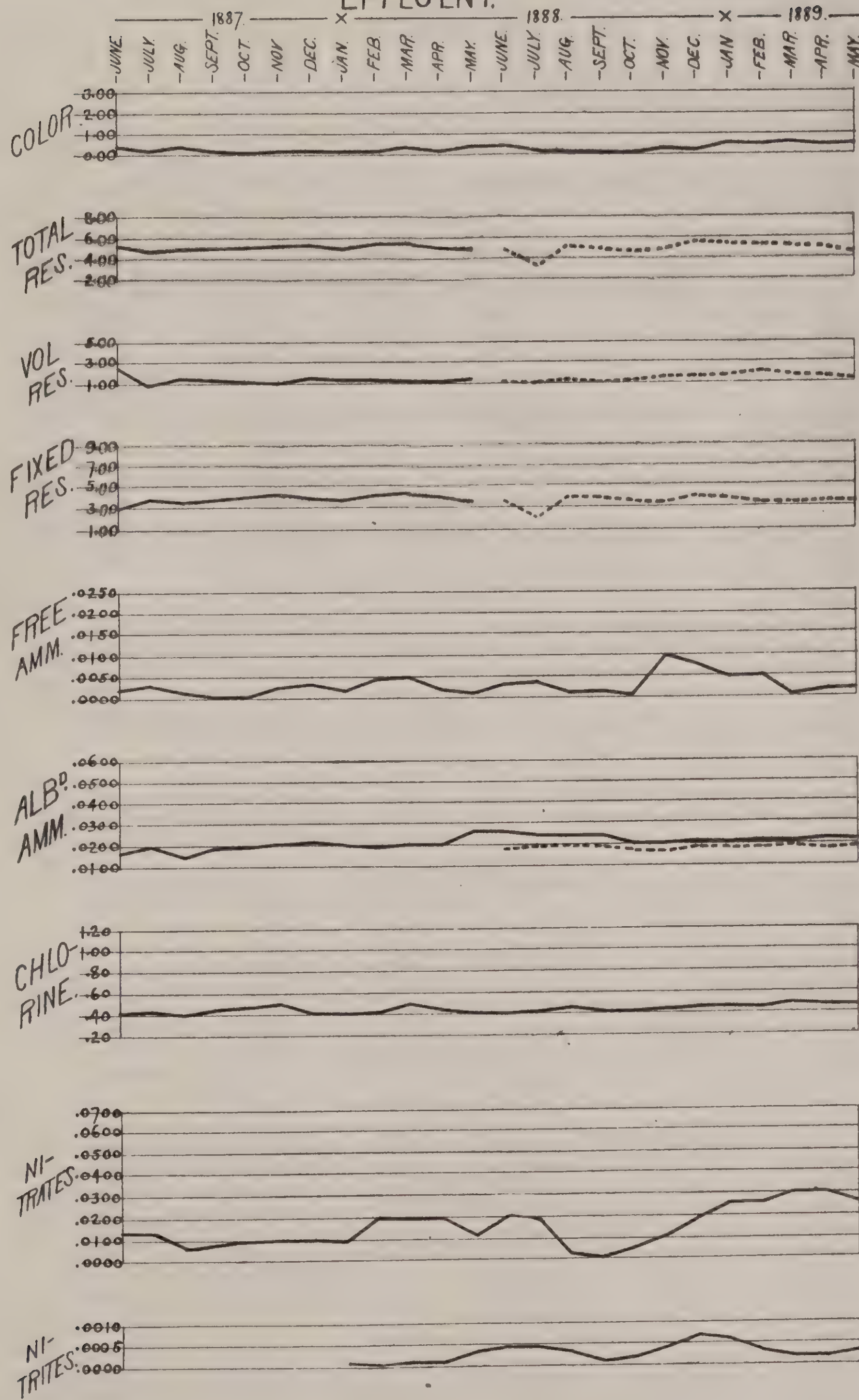


PLATE 51

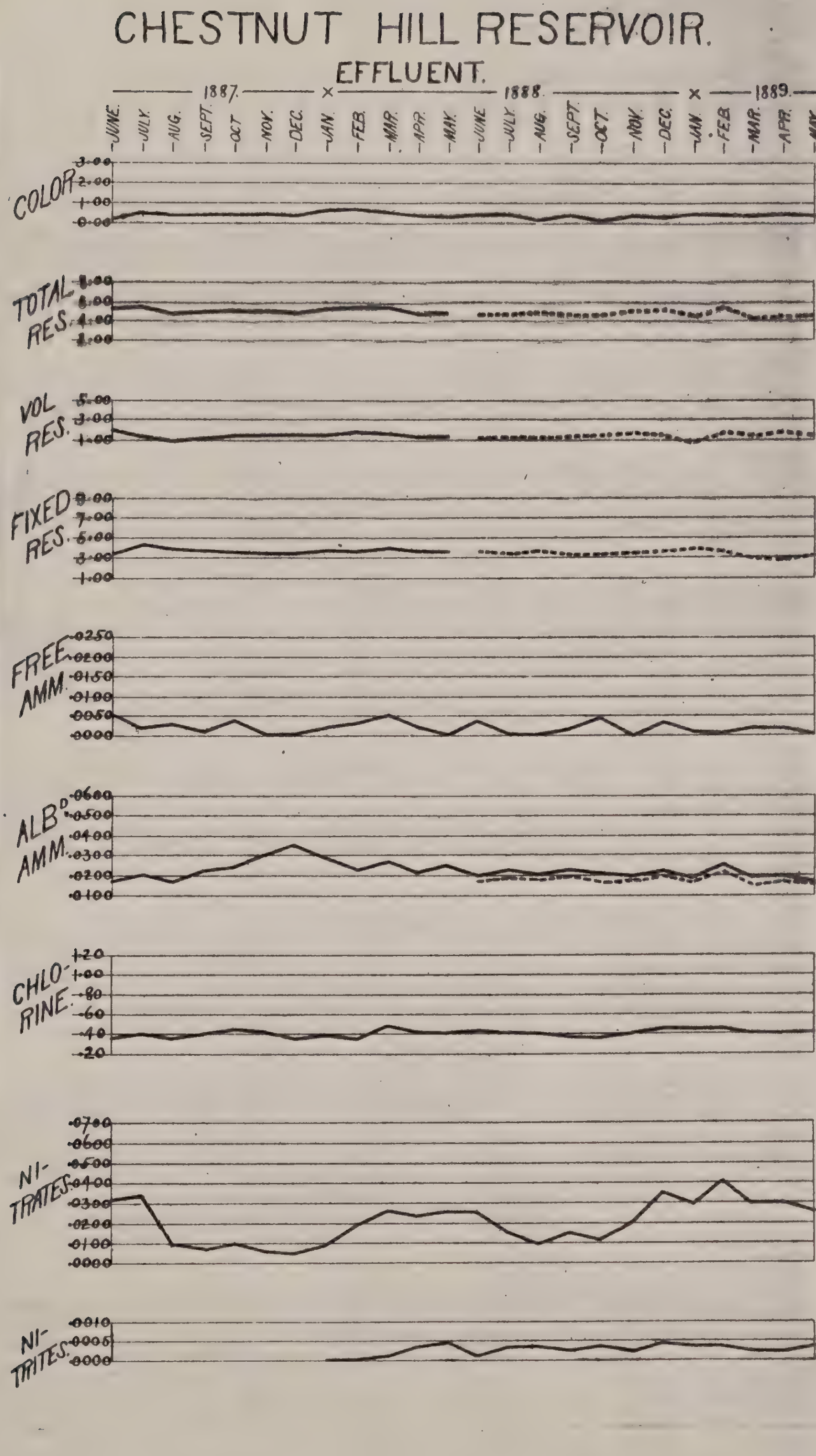
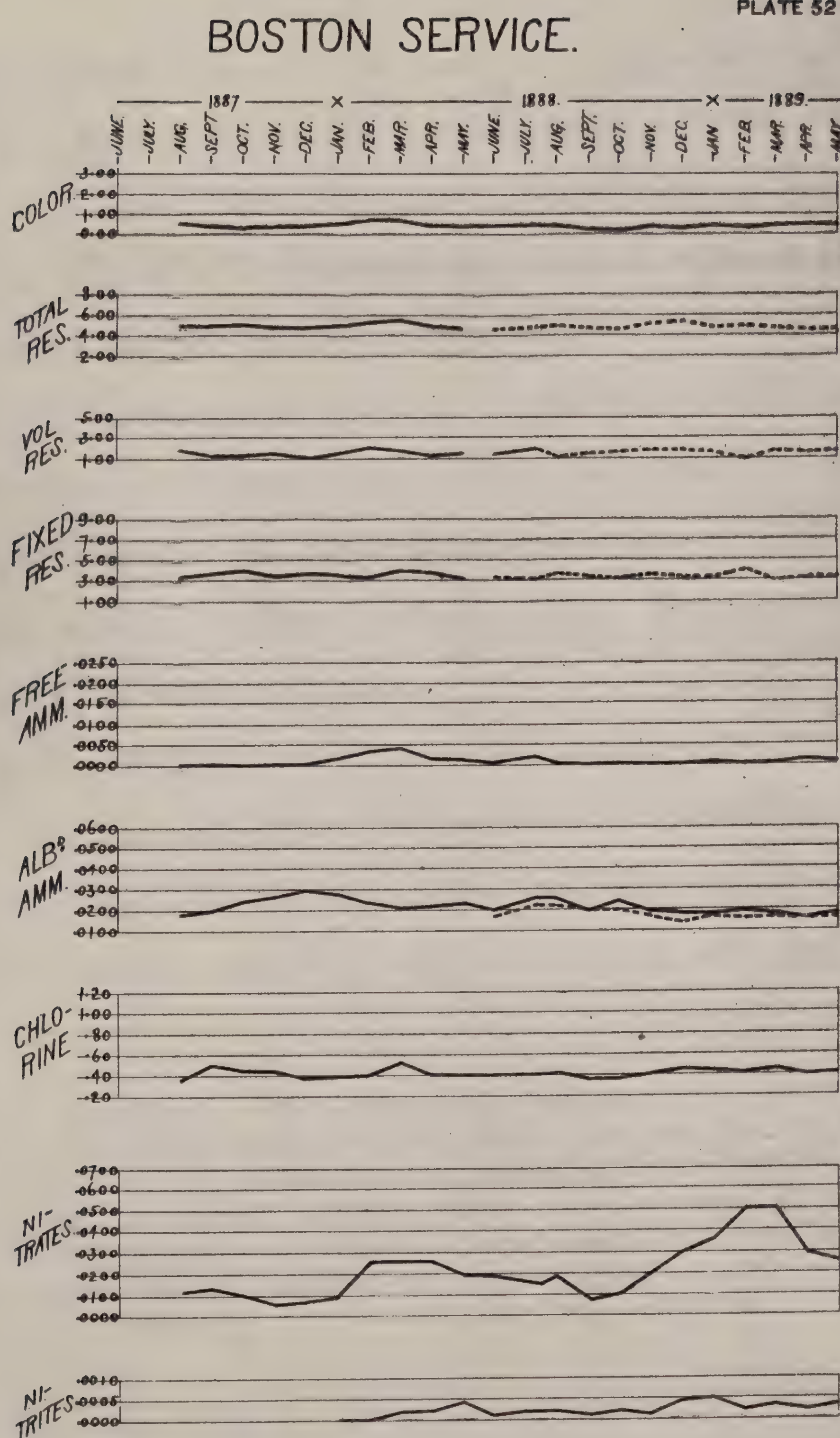

CHESTNUT HILL RESERVOIR.
EFFLUENT.
1887.
1888.
1889.
JUNE. JULY. AUG. SEPT. OCT. NOV. DEC. JAN. FEB. MAR. APR. MAY. JUNE. JULY. AUG. SEPT. OCT. NOV. DEC. JAN. FEB. MAR. APR. MAY.
COLOR
TOTAL RES.
VOL RES.
FIXED RES.
FREE AMM.
ALB^D. AMM.
CHLORINE.
NITRATES.
NITRITES.

PLATE 52


BOSTON SERVICE.
1887
1888.
1889.
JUNE. JULY. AUG. SEPT. OCT. NOV. DEC. JAN. FEB. MAR. APR. MAY. JUNE. JULY. AUG. SEPT. OCT. NOV. DEC. JAN. FEB. MAR. APR. MAY.
COLOR
TOTAL RES.
VOL. RES.
FIXED RES.
FREE AMM.
ALB. AMM.
CHLO-RINE
NI-TRATES
NI-TRITES

Bad Taste in the Water.

At various times in the past the Boston water has been affected by a bad taste, described commonly as a "fishy" or "cucumber" taste. In 1854, 1875 and 1881 the water was particularly offensive in this way. In 1879 it was slightly affected. In 1880 it was so bad that the common council ordered the Water Board to report on the "cause and prevention of the impurity of the water." It is generally in October that bad taste has been first developed. I will briefly review the facts connected with all but the first of the above events in chronological order. They have been, for the most part, already published.

Early in Oct. 1875 a bad taste was perceived in the City but could not be found either at Chestnut Hill Reservoir or Lake Cochituate. Complaint was made later that the water was unfit to use. The following statement will be found in City Doc. 80, 1876, p. 38;-

> At that date, (Oct. 26), the taste may be said to have been confined to the water in the pipes, but on the next day it was discovered in all parts of the Bradlee Basin of Chestnut Hill Reservoir, having spread through that large volume of about 500 000 000 of gallons of water in one night apparently. During the night there was a thunder-storm accompanied with violent winds, and agitation of the water may have aided in developing the taste.

In Lawrence Basin of Chestnut Hill Reservoir there was no bad taste.

Dr. Farlow pronounced the opinion, after careful examination, that the bad taste was not caused by "any living plant

ammonia due to sewage from Marlborough.

We now come to the consideration of the serious trouble in 1881. Basin 3 at that time contained a large amount of vegetable material; 280 000 cubic yards of loam, muck and earth and 12 000 stumps were subsequently removed. I find recorded in a diary that very early in the season of 1881 a large growth of algae took place in Basin 3; that we stopped drawing water from this source on May 13, 1881, on account of the algae (probably Clathrocystis); that on July 16 we were compelled to draw again from Basin 3 which caused a considerable growth to appear in Farm Pond; that on account of the low state of Boston's supply, 700 000 000 gallons were run into Farm Pond during August and September, thus exhausting Basin 3 in a very few weeks and soon displacing the water previously in Farm Pond, which can hold much less than that quantity; that on Oct. 1st I sent an assistant to Whitehall Pond and to the various mills and ponds on the Sudbury River, to see if algae were to be found, but that no considerable numbers were present. No water was drawn from Basin 3 after Nov. 1. The taste and smell had been so bad that a storm of indignation had swept over the city, and on the failure of local experts to detect the cause, Dr. Ira Remsen was summoned from Baltimore. He arrived in Boston on Nov. 4th. At this time no water was passing to the city from Basin 3, its gates having been closed, which justifies Dr. Remsen's remark that no water came from this source. The analyses made by this distinguished chemist shortly after

Nov. 4th showed that Basin 3 water was in worse condition than any of the other waters examined (except that of Pegan Meadows which were cut off from the supply), containing in 100 000 parts .0540 of one part albuminoid ammonia and .0226 free ammonia, while Farm Pond had .0404 alb. amm. and .0080 free amm. His report, as is well known, assigned as the cause of the badness of the water, the decay of sponge (an egg producing animal), which he located in Farm Pond.

An aqueduct is a favorable place for the sponge to live, because its walls furnish a firm support for the attachment of the animal, and the current of water brings a continuous supply of food. We have always been able to keep the Sudbury Aqueduct comparatively free from sponge, because the six months elapsing between the cleanings are not enough to give it a foothold; but during the summer of 1886 a vigorous growth was found on the invert. On Dec. 21, 22, and 23, 1885 the structure had received the usual winter cleaning. During the next season the work of improvement in Basin 3 was going on, its waters were all drawn out, and Stony Brook was carried through the old bed of the brook directly into Farm Pond for the supply of the city. Farm Pond throughout the summer was four feet lower than usual, to permit certain work of construction on the Farm Pond aqueduct, and thus the water from Stony Brook was delivered into the aqueduct almost directly. In July 1886 the self recording gauge showed that there was additional friction in the aqueduct due to obstructions.

On July 27, 28 and 29 the water was drawn off and sponge was found growing on the invert in two continuous lines three miles in length. The growth was generally from three to ten inches in diameter. From Bacon's waste weir to Waban Bridge the sponge gradually diminished. The patches were quite near each other and about an inch deep and like a soft carpet in texture. It was hard work to get it all off. We have never seen anything like it since. I now believe that the stream from Stony Brook furnished the nutriment. Had we waited until cold weather before removing it, decay would probably have set in with consequences proportionate to the quantity of sponge. It has been known to grow in large quantities in the main pipes of the Boston supply under 100 feet head, as stated in a paper published in Trans. Am. Soc. C. E. for May 1886.

Upon considering the general condition of Basin 3 and its very abnormal state in 1881 in connection with the fact that just before the bad taste appeared in that year the water of Farm Pond had been displaced by water from Basin 3, I have fixed upon Basin 3 as the real source of the trouble. I have written Dr. Remsen suggesting this idea, and he in turn suggests that Basin 3 water may have killed the sponge in Farm Pond. This is quite possible, although it seems to me from Prof. Hyatt's testimony before the Investigating Commission of 1882 that the sponge would die naturally in the latter part of the year. From my experience with the abnormal growth of the sponge in the Sudbury

Aqueduct in 1886 when the nitrogenous water from Basin 3 was turned almost directly into it, I am more inclined to the belief that an abnormal growth of sponge was first encouraged in Farm Pond by the quantities of the spores of algae and other food from Basin 3 in the early summer, and that afterwards it may have been killed by the very bad water from the bottom of Basin 3 which was impregnated with sulphuretted hydrogen; or it may have died naturally in October. In either event Basin 3 and not Farm Pond was responsible for the trouble; Farm Pond was in this case the innocent victim of popular indignation. In the case of the difficulty in 1875, shortly after a large amount of water had been drawn from the Sudbury, I believe that the sponge died first in the pipes in Boston, accounting for the fact that the taste appeared in some streets before it did in others; that later the sponge died in Bradlee Basin of Chestnut Hill Reservoir; and that there was none in Lawrence Basin because it has a muddy bottom which does not furnish the firm support necessary for the attachment of the sponge.

Shallow Flowage Improvement.

That overflowing the vegetable material in the basins would cause trouble, was foreseen by Prof. Nichols who said in 1874 in the Fifth Report of the Board of Health, p. 126;-

Another source of contamination to the waters of the Sudbury River will be that arising from the decomposition of the vegetable matter in the meadows overflowed in the formation of the proposed storage reservoirs (see Report of the Cochituate Water Board on an Additional Supply of Water, 1873, p. 34.) The expense of removing the entire accumulation of vegetable matter, and of the peaty soil in which it grows, would be too large to make such a removal practicable, although it would be desirable. The decomposition of the vegetable matter will render the water disagreeable to the taste and unfit for many uses, but the effect, to judge from experience in other places, will be temporary.

After the people of Boston had suffered greatly from the badness of the water in 1881, a petition was sent to the City Government signed by Henry J. Barnes, M.D. and other citizens which led to the appointment of a commission in Sep. 1882 to investigate the water supply. Other cities were visited as well as the sources of Boston's water supply and the testimony of experts was taken. The results were published in City Doc. No. 129, 1883. In the course of Dr. Wood's testimony Mr. M. S. Greenough of the Commission asked, "Is this matter in the water wholly in suspension, or in solution?"

Dr. Wood's answer was,- Largely in solution,- of course there is a good deal of insoluble matter which is brought from the present reservoirs and basins, and which is undergoing decomposition. The products of that decomposition are largely soluble in water. Take sulphuretted hydrogen. I think all of you know that at the time the first dams were built, and the water was let into those basins, a piece of cloth saturated with acetate of lead, and hung upon the lee side of the basins, very quickly

became blackened from the sulphuretted hydrogen blowing from the ponds, etc.

The following is an extract from the report of the Commission;-

The fact is now unquestionable, in the judgment of the Commission, that the only way properly to construct a basin is to take the loam all out. X X X X X

The water from the river and from Stony Brook contains an amount of organic matter, which though varying in quantity is yet always in excess. If the basins had been properly prepared the water would, by standing in them, lose by deposition and oxidation a quantity of the matter held in suspension or solution, sufficient to render the water purer and perfectly healthy. It has, however, been shown by careful analysis, executed for the Commission by Prof. Wood, that the water instead of losing organic matter in the basin actually takes it up, and although it loses some at Chestnut Hill Reservoir, it still contains too much in Boston.

This commission recommended among other things an improvement, which has generally been known in the Water Department as "removing the shallow flowage," for the purpose of securing as much as eight feet depth of water everywhere; and appropriations of $80 000 for Basin 2 and $125 000 for Basin 3 were soon afterwards made by the City Government for the purpose of carrying out this recommendation. The work consisted in filling up some shallow places with earth and excavating other shallow places so as to make them eight feet deep, the quantities of cutting and filling being made equal. The banks were generally given a slope of 3 horizontal to 1 vertical and were covered with gravel. In all exposed situations where the wind and waves have a long sweep rip rap ~~is~~ was added to the gravel. In Basin 2 about 140 000 cubic yards of muck, loam and gravel were handled, and in Basin 3 about

280 000 cubic yards. From Basin 3 twelve thousand stumps were removed. In the year 1883, which was very dry, nearly the whole of the shallow flowage improvement of Basin 2 was finished and a very small proportion of that of Basin 3. In 1886 that of Basin 3 was completed.

To show whether this work affected the quality of the water, the evidence of chemical determinations of the ammonias is submitted in tabular form.

	Albuminoid Ammonia			Free Ammonia		
	BEFORE	AFTER IMPROVEMENT		BEFORE	AFTER IMPROVEMENT	
BASIN 3	Dr.Wood 21 Analyses	Dr.Wood 12 Quarterly Analyses	Dr.Drown Monthly 2 yrs.	Dr.Wood 21 Analyses	Dr.Wood 12 Quarterly Analyses	Dr.Drown Monthly 2 yrs.
Influent	.0278	.0258	.0309	.0062	.0036	.0047
Effluent	.0327	.0239	.0285	.0082	.0049	.0049
Ratio of effluent to influent	1.18	0.93	0.92	1.32	1.36	1.04
BASIN 2	One Analysis	Dr.Wood 7 yrs.	Dr.Drown Monthly 2 yrs.	One Analysis	Dr. Wood 7 yrs.	Dr.Drown Monthly 2 yrs.
Influent	.0192	.0251	.0283	.0011	.0033	.0016
Effluent	.0302	.0262	.0296	.0005	.0047	.0008
Ratio of effluent to influent	1.57	1.04	1.05	0.45	1.42	0.50

In the case of Basin 3 the mean of 21 analyses before July 1886 is compared with the mean of 12 analyses since Jan. 1887. The free ammonia shows a reduction from .0062 to .0036 and from .0082 to .0049; it is diminished by about one third part.

The effluent, since the improvement as well as before, has somewhat higher free ammonia than the influent, indicating that some decay of organic matter still takes place in Basin 3. Of albuminoid ammonia the effluent contains less since the improvement than it did before and the influent about the same as before. The albuminoid ammonia in the effluent averaged before the improvement 18 per cent. greater, and since the improvement about 7 per cent. less, than in the influent; here is a distinct gain.

As for Basin 2, Dr. Wood expressed the opinion before the Investigating Commission in 1882 that the water was then made worse during its passage through Basin 2, but that opinion was based only upon single analyses of the influent and effluent. For the want of more analyses we cannot claim to have decisive chemical evidence as to what effect has been produced by the shallow flowage improvement upon the water passing through Basin 2. If we could be sure that, as appears from the one analysis, the albuminoid ammonia before the improvement increased 57 per cent. in passing through the basin, we could claim a marked gain; for since the improvement it increases only 4 per cent. on an average of several years. There was another analysis of the effluent of Basin 2, but not of the influent, made by Dr. Wood, 31 Oct. 1882 and recorded in Table XI, which shows a large amount of albuminoid ammonia, .0388.

Dr. Drown's monthly analyses for the two years, June '87 to May '89 are generally confirmatory of the results obtained by

Dr. Wood since the shallow flowage improvement.

If chemical improvement of the water can be ascribed to the partial stripping of the soil from the basins, (and I am inclined to think it can) then we have important evidence of the practical benefits resulting from the shallow flowage improvement. In the construction of Basin 4 all of the surface was stripped at a very great cost. If the success of this policy is measured by the excellent chemical showing that it has made in contrast to all the other Boston waters, then the precedent may well prove a wise one to follow in the future. The poor condition of the water in Whitehall Pond, in which decomposition has been going on for many years and has not yet ceased, is only the natural consequence of the flooding of a wooded and swampy area. (See chemical Table IX and Plates 25 and 26, also City Doc. No. 102, 1874, p. 43.) Certainly water to be used for domestic purposes should not be impounded where there is a large mass of vegetation, to injure the water. It is impossible in the present state of experience to determine whether absolutely the whole of the loam should be removed; but where there is a risk of so much harm it is best to err on the safe side.

Pollution to Aqueducts.

The Cochituate Aqueduct extends from the northerly division of Lake Cochituate to Brookline reservoir a distance of 14.63 miles. It is 6.33 ft. high and 5 ft. wide, built of two rings of bricks without backing. The section is egg shaped large end down; from settlement and from strains due to the forcing through the aqueduct of larger quantities of water than it was designed to carry, it has been cracked and distorted throughout the greater part of its length, so that it is not water tight. Wherever the water table in the ground outside is higher than the water in the aqueduct, springs force their way through the bottom and sides; where the water inside is higher than the ground water, leakage takes place into the surrounding soil. Where the line passes through an uninhabited district this effect is of little consequence from a sanitary point of view, although even under these conditions large quantities of infusoria and other microscopical organisms are brought into the structure, staining the brickwork as if it had received heavy coatings of ochreous paint. Where the line passes through thickly settled villages and near to dwellings there is danger of sewage contamination.

A number of years ago a considerable quantity of land belonging to the city along the line, and in part directly over the aqueduct, was sold by the Cochituate Water Board, under a mis-

taken sense of economy. I recently found a cesspool on one of these pieces, situated directly over the brickwork and leaking into the aqueduct; but there are still in close proximity to the aqueduct other cesspools over which the city has no control. An alarming amount of sewage leaks into the Brookline tunnel through seams in the rock.. A few years ago the city contributed towards the building of a sewer to deflect the drainage of the houses in the immediate vicinity of the tunnel, but this has not wholly removed the danger. It is possible that the sewage which now finds its way into the aqueduct at this point comes from considerable distances and by obscure routes.

My experience has shown that from a sanitary standpoint it is very undesirable to build an aqueduct in tunnel. It should be built as far as possible above the water tables of the ground through which it passes. When the head of water is considerable it is extremely difficult to build a perfectly water tight structure.

The Sudbury River Aqueduct extends from Farm Pond to Chestnut Hill Reservoir, a distance of 15.89 miles. It is 9 ft. wide by 7 ft. 8" high. It is much more substantially built than the Cochituate Aqueduct, but there are a number of places where the water from the outside leaks in, notably in the tunnels. The total length of the tunnels is 1.62 miles. When the land directly over these tunnels is thickly settled the danger to the purity of the water will be increased. On portions of the lines of both

aqueducts the country is rapidly filling up and every house contributes its quota of drainage to the subsoil. The land plans should be thoroughly studied and such pieces acquired as are necessary to protect the purity of the water.

FILTRATION.

Having now considered many of the evils which naturally attack the purity of a surface water supply like that of the City of Boston, even where the water is collected in large quantity and in reservoirs prepared with the greatest care, the question naturally arises, Is there a remedy? I have already pointed out how the quality of the water can be largely protected by sanitary measures enforced at the sources. Supposing the most perfect systems are devised and carried into effect on these, or other lines of action, the question still remains,- Is a surface supply, stored in open basins where organisms can flourish, and without filtration, proper drinking water? It is certainly safer to drink the water coming from as good a source as Lake Cochituate, or Sudbury River than to drink average well water, for in the latter case the slightest amount of polluting matter bears such a large ratio to the quantity of water in the well that injury to the water and consequent disease are likely to occur. Testimony from all over the world uniformly confirms this assertion. On the other hand, instances are rare of disease whose cause can be traced to a large public supply, because there is an enormous dilution of any impurities that may exist. Though I firmly believe that the Cochituate and Sudbury waters are perfectly healthful under their present conditions, I conclude from experiments on a small scale, carried on during the past two

years, that there is a considerable amount of matter, chiefly vegetable, which it would be worth while to remove from those waters before they are used. I have arrived at the conclusion that our standards of quality for public water supplies have not been high enough, and that they need to be raised. Water is almost the cheapest necessity with which a community provides itself, and, where it is not of unquestionable purity, evils arise, whose extent it is difficult to measure. Looking at it merely from the economical standpoint, fastidious people supply themselves with spring waters, delivered in barrels and bottles, which is expensive. It is within the possibilities of scientific practice to furnish a public water supply of almost any standard that the people choose to pay for. The future will probably demand higher standards of quality, greater intelligence and care in supervision and maintenance, and perhaps modified methods of construction.

It has been maintained that the dangerous properties of water could not be removed by filtration, but the latest investigations and experiments have largely modified this belief. The literature on this subject is already very voluminous. Thanks to the energy and ability of the State Board of Health of Massachusetts, it is unnecessary to go outside of the limits of the State for the latest information on this subject. From the results of the Lawrence experiments already published, it is apparent that perfect nitrification and a complete purification are accomplished by intermittent filtration, and by that means

alone, importance being attached to the aeration of the filter during the intervals between successive charges of water. By judicious intermittent filtration carried on very slowly all the organic matter can be destroyed, the color removed and a very bad water turned into a clear, sparkling and healthful water. The admirable experiments carried on at Lawrence have already thrown a new light on many of the difficult points connected with the subject. More complete results will soon be made public.

Upon many water supplies in Europe, notably in London and Berlin, filtration has been resorted to. The London filters are run on what is known as the continuous system, that is, the water is passed continuously through the sand and gravel at fixed rates of flow. It has been found that the slower the rate the more perfect the purification, and from long experience there is no difficulty in adjusting the rate of flow to the quality desired. By this means the filthy and highly polluted water of the Thames is robbed of many of its disagreeable properties before being distributed to the people, and London is called one of the healthiest of cities.

The following extract is taken from the report of The Rivers Pollution Commission:-

The Thames, above the intake of the respective water companies, receives the sewage from a large number of towns and other inhabited places, the washings of a large area of highly cultivated land, and the filthy discharges from many industrial processes and manufactures. The river is used for bathing, for the washing of sheep and cattle, and of dirty linen; and the putrid carcasses of animals float upon its surface. It is the common water way for a large amount of polluting matter, much

of which is at times dangerous to the health of persons who use even the filtered water for dietic purposes. In time of flood, a large proportion, both of the suspended and dissolved filth, is conveyed down to the intakes of the metropolitan water companies; and in ordinary weather a considerable portion of the soluble organic matter of sewage discharged into the river and its tributaries likewise makes its way down to the works of the water companies, and is still present in the water distributed by them in London. The water is, nevertheless, when efficiently filtered, free from any offensive taste or odor.

Wanklyn says "filtration renders Thames water all that can be desired for the supply of the metropolis." The chemical properties of water are considerably improved even by continuous filtration. From some of the tables furnished by Wanklyn it will be seen that by filtration free ammonia is reduced in the London water from 0.045 to 0.010, and albuminoid ammonia from 0.28 to 0.006, presumably parts per million.

The only filtration works in this country modelled after the English practice are at Poughkeepsie, N.Y.. Recent analyses under Dr. Drown's direction of the water before and after filtration shows a reduction of the free ammonia from .0038 to .0012, of the albuminoid ammonia from .0198 to .0130 and of the total residue from 11.00 to 8.60, and a reduction in color of about one half. Dr. Drown writes, "there is a decided improvement in the water as the result of filtration not only in its general appearance but in its chemical composition."

Piefke, the engineer of the Berlin supply, and Fraenkel, a biologist of high technical skill, have written recently interesting monographs on the effects of continuous filtration from a hygienic standpoint. From these German experiments it

seems clear that, while the Berlin filters are not entirely germ proof, yet they remove an immense number of bacteria.

Filtration at the Sources of Supply.

As Boston is probably irrevocably committed to the development, improvement and protection of the Sudbury River and Cochituate sources of supply, first, by the large expenditures already made, and second, by the fact that it would be extremely doubtful if better results could be secured for the same money elsewhere, I have been led to the conclusion that we should look forward to the possible conditions of the future when the towns now upon these areas will naturally have grown. The systems of sewerage adopted, and likely to be adopted, will provide for waste matters from houses and other buildings, but not for the street wash and surface drainage which is of an objectionable nature, large in quantity, and passing into the brooks after every rain. A street in a thickly settled town receives more filth than in a small village; and in a thinly settled place the street wash may flow freely over adjacent fields, and be considerably purified before it gets into the brooks; whereas, when the territory becomes more fully occupied, such discharge is not permitted, and channels are constructed, generally beneath the

ground, which conduct the street water directly into the nearest water course. How injurious this kind of drainage may become in many towns in the future, can be realized by watching at present the filthy street washings which pass into Pegan and Angle Brooks after every shower. This trouble might perhaps in a number of cases be much mitigated, if not entirely overcome, by acquiring a few tracts of land near the brooks and deflecting the flow at certain times upon a properly prepared filtering area for the purification of the water before allowing it to pass into the basins. In some situations this can be accomplished by gravitation, at moderate cost. At any rate, wherever such tracts of land exist they might be secured before it is too late. Even if filtration shall be carried on nearer the city, this will be a useful auxiliary. The whole subject, however, is one which demands the utmost care and prolonged study. Should it be decided, for instance, after investigation, that it is desirable to filter the Sudbury and Cochituate supplies, it would require several years of experiment and planning to ascertain the best practical method to pursue.

Your Board, acting with commendable promptness, have already begun initiatory steps in this direction. An experimental plant, modelled closely on the Lawrence tanks, is now in process of erection at Chestnut Hill Reservoir, and it is hoped will be put into operation early in the season. Prof. Thomas M. Drown ~~will have~~ has charge of the chemical work, and Hiram F. Mills, C. E.

is the consulting engineer. By means of this plant it will be possible to study the various effects of continuous and intermittent filtration on the Boston water, and to determine approximately the purifying power of different combinations of filtering sands.

Precipitation is another method sometimes resorted to for the purification of water. The so called mechanical filters ~~wherein~~ in which alum is used, are in fact precipitation processes, the organic matter is largely thrown down, or coagulated, and subsequently left in the filter to be washed out. The following extract from the report of the State Board of Health of Massachusetts, for 1888, p. 7, gives the results of the experiments made at Brockton with an alum filter;-

> Experiments have been made by the Board at Brockton and elsewhere with various appliances for rapid artificial filtration through sand, with and without the help of alum. These filters have acted continuously, except when the filtering material was being washed.
>
> In all of these experiments, when sand alone was used, the number of organisms was somewhat reduced, sometimes to one-third and sometimes to one-quarter; but with the deeply colored Brockton water of August and September the filtered water had the same appearance as the water of the reservoir, and the chemical analyses showed a very imperfect removal of the green growth. Such filtration would not be at all satisfactory.
>
> When alum is used with the sand, the number of microscopic organisms is reduced to a greater degree, depending upon the amount of alum used. The ordinary amount claimed to be used was one pound of alum for twenty-five thousand gallons of water. The experiments showed that this amount had no effect upon the color, and had reduced but little the number of bacteria; neither was the color reduced by two pounds, but four pounds reduced the color and the number of bacteria a little more than one-half, and reduced the microscopic organisms to about ten per cent. Six pounds of alum for twenty-five thousand gallons of water reduced the color to one-eighth of its original depth, reduced the bacteria to one-tenth, and the microscopic organisms to one per cent.

of the original number; but there was added to the water a large amount of ammonia, and about one part in one hundred thousand of combined sulphuric-acid. The appearance and taste of this water was satisfactory; but the Board of Health cannot advise the use of water which has passed through and dissolved this amount of alum.

Biological Laboratory.

Investigations made under the direction of your Board during the past three years having shown the desirability of having a small laboratory attached to the works, in which systematic examinations of the water might be made, your Board very liberally provided means by erecting at Chestnut Hill Reservoir a small building which was finished and put into use in the autumn of 1889. The work consists almost entirely of microscopical examinations, and as this constitutes only one branch of the examination of water I urgently recommend that the making of chemical analyses be at once begun, connecting and corresponding with the biological work. Bacterial cultures should also be made. All this can be added with but moderate expense in addition to that already incurred; and we should then have at all times a complete instead of a partial knowledge of the water. Mr. G. C. Whipple C. E. is the biologist in charge of the laboratory.

The following is an outline of the biological work connected with the laboratory.

Samples of water are collected weekly from the following places:- Lake Cochituate, Basins 2, 3 and 4 and the brooks flowing into them, Chestnut Hill Reservoir, both in the middle of the reservoir and at the gate houses, Brookline Reservoir gate house, and several taps in the city. Wherever the water is deep samples are taken from three points in the same vertical line, viz.;- one foot below the surface, mid-depth, and a point a few feet above the bottom. Collections are made in glass-stoppered bottles holding over a gallon. The bottle having been weighted and lowered to place, the stopper is pulled by means of an attached cord; when the bottle is full it is drawn rapidly to the surface, sealed, labelled and sent to the laboratory. A thermometer is always lowered with the bottle and read before removal from the water, so that the temperature of the samples is correctly ascertained.

The operations in the laboratory may be divided into two parts, Concentration and Examination.

Concentration:- A filter is prepared by fitting into the lower end of a glass funnel a plug of wire cloth tightly wound and having its upper surface ground flat on an emery wheel. On this plug is placed a layer of pure quartz sand (60-80) about one centimeter deep. Five hundred c.c. of the sample are put through this filter, the effect of which is to remove the organisms and the dirt that may have been in the water and to collect them on the sand. The plug is then carefully removed, and the sand washed into a test tube with five c.c. of filtered water. Organisms

and sand thus being mixed up together, the water is decanted into a second test-tube, with the result that the organisms flow off with the water, while the sand by virtue of its greater specific gravity remains behind. Thus the five c.c. contain all the suspended matter originally present in the five hundred c.c. of the sample.

Examination:- One cubic centimeter of this concentrated sample is put into a rectangular cell (50 mm. x 20 mm.) made by cementing a brass rim on to an ordinary glass slip. This cell having a depth of 1 mm., has a capacity of just one cubic centimeter, so that when the cover glass is put on, the space is entirely filled by the sample. The microscope used for counting, consists of a Bausch and Lomb stand fitted with a mechanical stage of a special construction, a 1/2" objective, and a No. 3 eye-piece. An eye-piece micrometer, consisting of a ruled square is so arranged as to cover a space of one square millimeter on the stage. The cell containing the sample having been placed on the stage, the number of organisms contained in one of these squares is exactly counted and their species determined. The position of the cell is then changed and 19 other squares counted. From these counts the number of organisms in the original sample can be easily computed. Results are expressed in "number per cubic centimeter." The classification of species found to be most convenient is the following.- Diatomaceae, Desmidiaceae, Chlorophyceae, Cyanophyceae Algae-Fungi, Rhizopoda, Infusoria, Rotifera, Crustacea, Zoosphores

Amorphous matter (or Zoogloea), Miscellaneous. For determining species and for work with high powers the laboratory is provided with a Zeiss microscope, and an extensive series of objectives and eye-pieces. There is also an elaborate photo-micrographic camera; and every facility is at hand for taking photographs of the organisms found in the water.

After the samples are examined biologically, a record is made both in book form and on profiles, so that the changes taking place in the water of any source can be seen at a glance. The record of the living organisms and of the amorphous matter is kept separate.

The system under which the laboratory is conducted was principally designed by George W. Rafter, Civil Engineer, of Rochester, whose skill in this department is well known. I am also indebted to Prof. William T. Sedgwick, of the Massachusetts Institute of Technology, for valuable advice. I have every assurance that there is no more perfect system, and none exactly similar in use anywhere. As far as this biological work goes, there is little to be desired. No changes in the life of the Sudbury or Cochituate water can take place, without the fact being noted and the kind of life recorded.

By waiting until a bad taste appears in the water before beginning investigation, the source of the trouble may be entirely lost through delay, and only the evil results left. This has been Boston's experience several times in the past. Perhaps

after several years of investigation and record, results of importance to the management of water supplies may be reached. Already during the few months that the present system has been in operation, I have had occasion to avail myself of the information conveyed through the biological analyses in the practical management of the water, and I expect still more valuable results in the future.

As an example of the kind of ~~the~~ investigations which are made in the laboratory outside of the ordinary routine work, I may mention this instance. During the middle of September of 1889, a peculiar appearance was noticed in the brook below Dam 4 and this effect was soon traced to the bottom of the basin. The leakage through the lower gates under fifty feet head, though small in amount, was sufficient to make the water muddy. At depths of 10,20 and 30 feet the water in the basin was perfectly clear. At 35 feet a slight milkiness or cloudiness appeared, which at 40 feet was quite marked. Other samples were taken further up the basin, with nearly the same result viz. the cloudiness appeared at about 30 or 35 ft. line.

On Oct. 11 the condition of affairs was practically unchanged. At this time the temperature of the surface was 54° Fahr. at mid depth 57° and at bottom 53°.

Four samples, examined microscopically, showed rather more amorphous matter at the bottom than at the surface. In the case of the bottom sample, although the sand filter removed all the

organisms and masses of amorphous matter, the filtrate still maintained a cloudy appearance. After special filtering apparatus was arranged, this cloudiness was entirely removed by repeated filtration.

On Oct. 11, a series of careful temperature observations was begun, which was continued with tolerable regularity until the turbidity ceased. For these measurements a thermometer with a porcelain scale was used. This was lowered to the proper depth in a demijohn holding two gallons. After the cord had been drawn and the demijohn filled, it was allowed to remain for at least one minute, that the glass might acquire the temperature of the surrounding water. It was then drawn rapidly to the surface, and the reading taken while the thermometer was in the water. The following table gives the temperatures from Oct. 11 to Oct. 29, and the grade of the water surface. The mid depth samples were taken 20 ft. and the bottom samples 40 ft. below the surface.

Date	Grade	°Fahr. Surface	°Fahr. Mid depth	°Fahr. Bottom
Oct. 11	215.11	54.0	57.0	53.0
Oct. 14	214.96	53.6	53.4	51.4
Oct. 15	214.41	53.2	53.2	53.2
Oct. 17	214.56	54.4	53.4	53.1
Oct. 18	214.56	53.4	52.2	52.0
Oct. 19	214.52	52.2	52.6	52.6
Oct. 21	214.49	52.3	52.1	51.7
Oct. 23	214.47	50.8	50.0	50.8
Oct. 26	214.53	50.8	50.0	49.9
Oct. 29	214.53	50.2	50.0	50.0

On Oct. 14, the turbid water seemed to be rising, and on the following day, the temperature being uniform at all three

XX

WATER ANALYSES. BOSTON WATER WORKS.

PARTS IN 100,000. By Dr. Thomas M. Drown

NO.	LOCALITY.	DATE OF COLLECTION.	DATE OF EXAMINATION.	ODOR. COLD.	ODOR. HOT.	APPEARANCE. TURBIDITY.	APPEARANCE. SEDIMENT.	APPEARANCE. COLOR.	RESIDUE ON EVAPORATION. TOTAL.	RESIDUE ON EVAPORATION. LOSS ON IGNITION.	RESIDUE ON EVAPORATION. FIXED.	RESIDUE ON EVAPORATION. CHANGE ON IGNITION.	CHLORINE.	NITROGEN. ALBUMINOID AMMONIA. Unfiltered.	NITROGEN. ALBUMINOID AMMONIA. Filtered.	NITROGEN. FREE AMMONIA.	NITROGEN. AS NITRITES.	NITROGEN. AS NITRATES.	~~OXYGEN~~ CONSUMED.	HARDNESS.
	Basin IV – Surface	Oct. 12. 1889		none	Faintly vegetable	very slight	very slightly flocculent	1.0	4.10	1.95	2.15	Peaty	0.25	0.0300		0.0040	0.0002	0.0070		1.7
	" 20 ft. down	" " "		none	Faintly vegetable	very slight	very slightly flocculent	1.1	4.60	1.90	2.70	Peaty	[illegible]	0.0258		0.0046	0.0002	0.0070		1.7
+	" 35 ft. down	" " "		none	Faintly vegetable	Distinct	Slight flocculent	0.9	4.50	1.75	2.75	Peaty	0.25	0.0198		0.0036	0.0004	0.0090		1.7
	" 39 ft. down 3 ft. above bottom	" " "		Faintly earthy	Faintly vegetable	Decided	Slight flocculent	1.2	4.80	1.70	3.10	Peaty	0.24	0.0224		0.0090	0.0005	0.0070		1.7
*	" Surface	Oct. 17, 1889			Faintly vegetable Sweetish	very slight	very slight	1.0						0.0316		0.0038	0.0000	0.0050		
*	" Mid-depth	" " "			Distinct vegetable Sweet.	very slight	very slight	1.0						0.0276		0.0030	0.0001	0.0050		
*	" 3 ft. above bottom	" " "			Faintly vegetable Sweet.	very slight	very slight	1.0						0.0260		0.0032	0.0000	0.0070		
	" 1 ft. below surface	Oct. 19, 1889		Faintly earthy	Distinct vegetable Sweetish	slight	Slight flocculent	[filtered] 1.1	4.16	1.90	2.25	Blackened odor peaty	0.25	0.0242	0.0218	0.0034	0.0001	0.0060		
	" 20 ft. down	" " "		Faintly earthy	Distinct vegetable Sweetish	slight	Slight flocculent	1.0	3.80	1.40	2.40	Blackened odor peaty	0.26	0.0246	0.0234	0.0038	0.0001	0.0050		
	" Bottom	" " "		Faintly earthy	Distinct vegetable Sweetish	slight	Slight flocculent	1.1	4.65	1.90	2.75	Blackened odor peaty	0.24	0.0232	0.0210	0.0028	0.0001	0.0060		
	" Surface	Oct. 21, 1889		very faintly vegetable	Decided vegetable [illegible]	very slight	very slight	1.2	4.28	1.60	2.68	Blackened odor peaty	0.25	0.0248	0.0232	0.0026	0.0001	0.0020		
	" 20 ft. below	" " "		Faintly vegetable	Faintly vegetable	slight	slight	1.2	4.10	1.45	2.65	Blackened odor peaty	0.27	0.0250	0.0244	0.0028	0.0001	0.0070		
	" 40 ft. below	" " "		very faint or none	very faint vegetable	slight [more than preceding]	very slight	1.0	4.55	1.85	2.70	Blackened odor peaty	0.26	0.0282	0.0246	0.0032	0.0000	0.0070		

\+ on Oct. 12 the sample ~~[illegible]~~ 35 ft. down was taken at the highest grade at which the turbidity was noticed

* on Oct. 17 the quantity furnished the chemist was not sufficient to make all the determinations

The colors were the same filtered & unfiltered.

Had there been a few more analyses, particularly before the 12th we should have had a more complete history from the chemical standpoint.

It looks as if the organic matter after going through certain changes during the summer had settled to the bottom and gradually accumulated. Nitrification could not very well take place at such depths and there the finely divided matter remained until October when it came to the surface to take the place of the cold water sent to the bottom, disappearing very quickly under the effects of oxidation at the surface. The chemical analyses have shown for several years that all of our stored waters are regularly worse in the autumn than at any other time owing apparently to the rise of the bottom water where impurities have been collecting during the summer. Mr F. P. Stearns, Chief Engineer of the State Board of Health, an accurate observer, has noticed the same phenomenon.

This indicates that to have the highest degree of purity a reservoir should not be too deep, for if oxygen cannot be brought into contact with the organic matter, nitrification cannot go on. The wind and waves exert their power to keep the water changed down to a certain depth.

Occasional examinations are made in the laboratory of other waters, and it has always been found that both in point of regularity and in number of organisms ~~formed~~ the Boston water in the service pipes is excellent. The annexed table gives re-

sults obtained during the week ending March 1, 1890. In determining the number of pieces of amorphous matter a certain sized piece is used as a standard. The amorphous matter consists of dirt and inorganic remains mixed with clusters of bacteria. It is sometimes called zooglea.

Number per c.c. 176

CITY	SAMPLE FROM	PLANTS	ANIMALS	TOTAL ORGANISMS	AMORPHOUS
Newton	Reservoir	1993	0	1993	284
"	Filter Gallery	17	0.5	17.5	33
"	Tap at Newton Centre	13	0.5	13.5	25.5
"	Reservoir	4996	0	4996	82
"	Tap at Newton Centre	63.5	0	63.5	21
Salem	Reservoir	1483	17	1500	102
"	Pipe into City	1571.5	5	1576.5	90.5
Mystic System	Reservoir, Somerville	1452.5	3	1455.5	428
" "	Tap in Chelsea	797	1.5	798.5	175
Springfield	Ludlow Reservoir	416	289	705	71
"	High service tap in City	259	175	434	127
"	Van Horn Reservoir	29.5	14	43.5	201
"	Low service tap in City	245	263	508	142
Lynn	Reservoir	449	48.5	497.5	152.5
"	Tap in City	260.5	8.5	269	157
Worcester	Leicester Reservoir	5.0	2.5	7.5	39
"	Holden Reservoir	464	6	470	118
"	Tap in City	11.5	13.5	25	54
Malden	Spot Pond	1	127	128	156
"	Eatons' Wells	0	0	0	0
Boston	Effluent G.House				
"	C. H. Reservoir	119	2	121	124
"	Tap at City Hall	78	0	78	65
"	Brookline Reservoir	103.5	2	105.5	115
Cambridge	Fresh Pond	65	3	68	284
"	Tap in City Hall	58.5	2.5	61	196
Brookline	Reservoir	35	2.5	37.5	43
"	Tap Mr. Fitz Gerald's	8.5	3.0	11.5	34
Lowell	Beacon St. Reservoir	9.5	1.0	10.5	77
"	High Service Res.	3	0	3	77
"	Tap in City (low service)	2	6.5	8.5	63
Taunton	Filter Gallery	17	0.5	17.5	33
"	City Hall	1.5	0	1.5	14.5
Lawrence	Reservoir	0.5	5.0	5.5	60
"	Tap in City	1.5	3.5	5.0	25

The following letter from Prof. William T. Sedgwick explains itself 127

Biological Laboratory.

Mass. Institute of Technology.

Boston, March 10th, 1890.

Desmond FitzGerald Esq., C. E.

Resident Engineer Boston Water Works.

Dear Sir:-

In reply to your note of Feb. 28th I beg leave to say that numerous biological analyses of Boston Drinking Water have been made in this laboratory from time to time during the past two years, partly in the regular course of instruction and partly as incidental work in connection with particular investigations, but always for our own purposes, and without reference to any special report. They are therefore only fragmentary, but so far as they go they are freely at your service or that of the Water Board. I can only regret that they are not more numerous.

In looking over our statistics of bacterial analysis it appears that the average number of living bacteria in 39 analyses of the tap water at the Institute during 1888 was 187, per cubic centimetre, the extremes being 1684 and 12. During 1889, 26 analyses gave an average result of 74 living bacteria per cubic centimetre, the extremes being 224 and 8. x x x x x x x x x x It appears to be a fact that the Cochituate supply was better, bacterially speaking, during 1889 than 1888, and in either

case it compares very favorably with many neighboring supplies, as well as with those more remote.

The city of Berlin, Germany, filters its drinking water through sand before serving it to the inhabitants. From July 1885 to April 1886 the city water thus purified contained in one supply 63 bacteria and in another 51 (average) per c.c. That of Boston (Cochituate) unfiltered as shown above during 1889 was 74. In Zurich, Switzerland, water from the lake is filtered and as delivered during 1886, contained 24 bacteria per c.c. Numerous microscopical analyses of Cochituate have also been made as a part of our work during the past year, and the microscopical organisms have varied from 12 to 200 per c.c. averaging about 68. They have consisted chiefly of diatoms (Asterionella, Synedra, Stephonodiscus, Tabellaria and Melosira), Algae (Chlorococcus, Anaboema, Clathrocystis, Coelosphaerium, etc.) and Infusoria (Dinobryon, Peridinium). These forms have usually appeared to be alive and in good condition, and this fact, added to the circumstances that but few bacteria, relatively were present shows that this water is, at present, comparatively free from matters undergoing decomposition. The microscopical organisms however are somewhat liable to decompose, and as they are easily removed by filtration it would seem to be the part of wisdom to separate them from the water. It seems to me that a patient and systematic study, both bacterial and microscopical, of the organisms inhabiting the Boston Drinking Water between its sources and the

service, especially if faithfully continued for several years would unquestionably throw much light upon the whole subject of pure water supplies, and result in marked improvements in our own. I may be permitted to add that the biological work already instituted by the Water Board appears to me to give evidence of precisely that liberal and progressive spirit which the citizens of Boston have always commended.

Very truly yours,

Wm. T. Sedgwick.

Appendix

Manufactures

	Districts	Number of Establishments	Estimated Total Number of Employees
I	Snake Brook	11	800
II	Pegan Brook	24	1500
III	Dug Pond	—	—
IV	Course Brook	0	0
V	Beaver Dam Brook	8	1500
VI	Farm Pond	1	150
VII	Basins I & II & Cold Spr. Bk.	2	4
VIII	Eastern Sudbury	6	580
IX	Indian Brook	5	1050
X	Western Sudbury	4	170
XI	Whitehall Brook	1	90
XII	Cedar Swamp	9	1015
XIII	Basin III	3	18
XIV	Stony Brook	5	300
XV	Angle + Bd. Mw. Brks	16	5000
	Totals	95	12,177

Following 18 pages have been compared with authentic records and corrected. [illegible] Hopson

DECISION OF THE SUPREME JUDICIAL COURT IN THE

CASE OF

AUGUSTUS P. MARTIN, MAYOR OF BOSTON,

vs.

LUTHER ELLIS GLEASON.

Preliminary Statement.

(From City of Boston's Brief.)

In 1846 the Legislature, by an act entitled "An act for supplying the City of Boston with pure water," authorized the City of Boston "to take, hold, and convey to, into and through said city the water of Long pond, so called, (now Lake Cochituate), in the towns of Natick, Wayland, and Framingham, and the waters which may flow into and from the same, and any other ponds and streams within the distance of four miles from said Long pond, and any water-rights connected therewith." Acts of 1846, Ch, 167, §1.

Persuant to this authority, and in part execution thereof, the city, in August 1846, took certain water and water-rights, described as, "all the waters of Long pond, so called, and other brooks and streams, whether permanent or temporary, entering into the same, and of all the bays, coves, and inlets thereof, and of the outlet of the same, and all the water-rights thereunto belonging, or in any wise appertaining."

August 19,1846,the city filed in the office of the registry of deeds for the county of Middlesex the foregoing description of the taking,and a statement of the purpose for which taken as required by said act of the Legislature. (See copy,page 4 of the report); and,as soon as the necessary works could be constructed, proceeded actually to use,and has ever since used,said waters for the supply of its inhabitants. ~~Pagen~~ Pegan brook is,and has always been,one of the streams entering into Long pond. (Report page 1.)

The defendant is the proprietor of a hotel in Natick,and all human excrement discharged from the water-closets,and all sewage of his hotel are discharged directly into said brook in sufficient quantity to contaminate its waters. (Report Page 1).

The City of Boston,by petition of its Mayor (St.1884,c 154) prays for an injunction to restrain the defendant from polluting this water supply.

DECISION OF THE SUPREME JUDICIAL COURT.

MARTIN vs.GLEASON.

C.Allen,J. Disregarding punctuation,as may properly be done in construing a statute (Cushing vs.Worrick,9Gray,385),and looking at the purpose and contemplated scope of Stat.1846,c.167, the City of Boston was authorized by section 1of that statute to take the water of Long pond,and the waters which may flow into and from the same,and any other ponds and streams within the distance of four miles from said Long pond,and any water-rights

connected therewith, so far as may be necessary for the preservation and purity of the same, for the purpose of furnishing a supply of pure water for the said City of Boston. This declared purpose relates back, and illustrates the extent of the authority conferred. Water-rights may be taken so far as may be necessary for the preservation and purity of the water. The words "and any water-rights connected therewith" are not limited to the immediate antecedent, namely, the "other ponds and streams" there referred to, but they also include Long pond itself, and the waters which may flow into and from the same. It was designed to give a broad and comprehensive authority, for the purpose of furnishing a supply of pure water for the city, and to confer ~~this~~ the power to take everything included within the meaning of the antecedent words, so far as might be necessary for the preservation and purity of the water. Section 15, imposing a penalty for wantonly or maliciously diverting the water, or any part thereof, ~~or~~ of any of the ponds, streams or water-sources which shall be taken by the city, or corrupting the same, or rendering it impure, confirms this view. Under this authority the city might lawfully take any water-rights connected with the waters flowing into Long pond, including the prescriptive rights which the plaintiff contends that he then had to discharge sewage into Pegan brook. It appears that this brook is and always has been a feeder of Long pond; and that the whole of it is within four miles of the pond. A prescriptive right to foul the waters of a stream is included under the term "Water-rights." This indeed is assert-

ed by the defendant in his answer. It is a right in respect to the water of the stream; and the statute conferred power to take all water-rights which might interfere with the purity of the waters taken. It is contended for the defendant that, if it was necessary to preserve the brook or the purity of the water, power was granted to the city to take the land on each side of the brook, and thus cut off any use either of it or of its waters; and, indeed that the water-rights could not be taken separately from the land. But it does not appear to us to be necessary, even if it was competent, for the city to take the land on the sides of the brook, in order to extinguish any prescriptive right to foul the water of it.

Assuming that the defendant has such prescriptive right; it is further contended that the city did not take it; but that the taking of the waters of the brooks and streams entering into Long pond, only appropriated the water as it flowed into the pond at the time of the taking, and subject to all legal burdens and uses then existing. This however, is too narrow a construction of the description of what was taken. The city, after reciting the whole of the first section of the statutes, took all the waters of Long pond, "and other brooks and streams, whether permanent or temporary, entering into the same, and all the water-rights thereunto belonging or in any wise appertaining, for the sole use and benefit of said city." This language does not exactly follow the language of the statute; but we cannot doubt that it is broad enough to include Pegan brook, and the taking of "all the water-rights thereunto belonging or in any wise appertaining," includes any right then existing to foul its waters. It is urged, by way of illustration

that,if a mill existed on the brook,the right to use the mill was not taken. But ti is not necessary to consider that question here. It does not appear that there was any mill on the brook. If ther was,the use of the water for turning its wheels might not foul the water,and might therefore be consistent with the purposes and rights of the city. But the right to use the brook as a discharge for sewage in large quantities,as practised by the defendant,is inconsistent with such purpose. If therefore,the defendant had any such prescriptive right to foul the water of Pegan brook,as he claimed,such right was taken and extinguished by the act of the city under the Statute of 1846; and by Section 6,of that act,the city was liable to pay all damages sustained thereby. The defendant,if he sustained damage might have applied by petition for the assessment thereof at any time within three years from such taking. This remedy was the exclusive one.

It was not seriously contended in the argument that the defendant has acquired a prescriptive right to foul the waters since the taking by the city in 1846. Such prescriptive right could not be acquired,because the fouling of the water since the right to foul it ceased,would be a public nuisance. Morton vs. Moore, 15 Gray, 576. Brookline vs. Mackintosh, 133 Mass., 225, 226.

Finally,it was contended for the defendant that,by reason of constructions erected by the city at the mouth of the brook, since the taking in 1846,the waters of Pegan brook,do not in fact contaminate the water of the pond; and that,therefore,the

city is not injured. It appears, however, as a fact, that the water of the brook is contaminated by the acts of the defendant. The city has a right to be protected against the necessity of maintaining works for the preservation of the purity of the water from such a cause. If the acts of the defendant in fouling the stream have made it necessary for the city to resort to extraordinary means for preserving the purity of the water of the pond, he cannot justify the continuance of such illegal fouling by showing that the city has thus far been able, by the maintenance of special works, to prevent the natural results of his acts.

The result is that the petition for an injunction is maintained.

INJUNCTION TO ISSUE.

PUBLIC STATUTES.

POLLUTION OF RIVERS AND SOURCES OF WATER-SUPPLY.

Sect. 96. No sewage, drainage, or refuse or polluting matter of such kind and amount as either by itself or in connection with other matter will corrupt or impair the quality of the water of any pond or stream hereinafter referred to, for domestic use, or render it injurious to health, and no human excrement, shall be discharged into any pond used as a source of water-supply by a city or town, or upon whose banks any filter basin so used is situated, or into any stream so used, or upon whose banks such filter basin is situated, within twenty miles above the point where such supply is taken, or into any feeders of such pond or stream within such twenty miles.

Sect. 97. The preceding section shall not be construed to destroy or impair rights acquired by legislative grant prior to the first day of July in the year eighteen hundred and seventy-eight, or to destroy or impair prescriptive rights of drainage or discharge, to the extent to which they lawfully existed on that date; and nothing therein contained shall be construed to authorize the pollution of any waters in this commonwealth, in any manner contrary to law; norshall it be applicable to the Merrimack or Connecticut Rivers, or to so much of the Concord River as lies within the limits of the City of Lowell. ,

Sect. 101. Whoever drives a horse on the ice on a pond , the water of which is used for the purpose of domestic water-supply for a city or town, shall be punished by fine not exceeding fifty dollars or imprisonment not exceeding thirty days . ~~period.~~

Sect. 102. The preceding section shall not apply to persons engaged in cutting or harvesting ice from such ponds, or in hauling logs, wood, or lumber.

Chap. 172, 1884. Whoever bathes in a pond, the water of which is used for the purpose of domestic water-supply for a city or town, shall be punished by fine not exceeding ten dollars.

Chap. 154, 1884. The Supreme Judicial or Superior Court, in term time or vacation, upon the application of the mayor of a city or the selectmen of a town interested, may grant an injunction against any violation of the provisions of Section ninety-six of Chapter eighty of the Public Statutes.

CHAP. 208.

Sect. 7. Whoever wilfully or maliciously defiles, corrupts or makes impure any spring, or other source of water, or reservoir, or destroys or injures any pipe, conductor of water,

or other property pertaining to an aqueduct, or aids or abets in any such trespass, shall be punished by fine not exceeding one thousand dollars, or by imprisonment in the jail not exceeding one year.

Sec. 8. Whoever wilfully deposits excrement, or foul or decaying matter, in any water used for the purpose or domestic water-supply, or upon the shore thereof within five rods of the water, shall be punished by fine nor exceeding fifty dollars, or by imprisonment not exceeding thirty days; and a police officer or constable of a city or town in which such water is wholly or partly situated, acting within the limits of his city or town, and any executive officer or agent of a water board, board of ~~town~~ water comissioners, or water company furnishing water for domestic purposes, acting upon the premises of such board or company and not more than five rods from the water, may without a warrant arrest any person found in the act of violating the provisions of this section, and detain him until complaint can be made against him therefor. But this section shall not be so construed as to interfere with the sewage of a city, town, or public institution, or to prevent boating, bathing, or fishing, the enriching of land for agricultural purposes by the owner or occupant thereof.

PRIVATE STATUTES.

1846

Chap. 167.

COCHITUATE WATER ACT.

Sect. 15. If any person or persons shall wantonly or maliciously divert the water, or any part thereof, of any of the ponds, streams, or water sources, which shall be taken by the city pursuant to the provisions of this act, or shall corrupt the same, or render it impure, or destroy or injure any dam, aqueduct, pipe, conduit, hydrant, machinery, or other property held, owned, or used, by the said city, by the authority and for the purposes of this act, every such person or persons shall forfeit and pay to the said city three times the amount of the damages that shall be assessed therefor, to be recovered by any proper action. And every such person or persons may moreover, on indictment and conviction of either of the wanton and malicious acts aforesaid, be punished by fine, not exceeding one thousand dollars, and imprisionment not exceeding one year, "or by confinement to hard labor in the state prison for a term not exceeding ten years."

1875. - CHAPTER 228.

AN ACT TO PRESERVE THE PURITY

OF THE WATER OF LAKE COCHITUATE.

189

Be it enacted, etc.;

Section 1.It Shall be lawful for the supreme judicial court, upon the application of the city of Boston, to grant an injunction against the discharge or any drainage or sewage matter, or pollution of any kind, into Lake Cochituate,or Pegan Brook, or any waters flowing into said lake or brook; PROVIDED, that this shall not be held to destroy the prescriptive right of any person or persons to discharge such matter into said lake or brook.

Sect. 2. The town of Natick shall have the right to divert the waters of any brook, rivulet, or stream, now running into Lake Cochituate, into which the sewerage or drainage of Natick now empties; PROVIDED, that nothing in this act shall be construed so as to give any right to said town to divert such brook, rivulet, or stream, into Charles River.

Sec. 3. This act shall take effect upon its passage.

May 19, 1875.

A landlord is liable for the acts of his tenant in polluting the waters of a brook, which is a natural watercourse running through the premises, by discharging sink water therein, if the building leased is adapted and intended to be used in the manner complained of, whether he retains control over the house or not.

In an action for polluting the waters of a brook, which is a natural watercourse, if the injury to the plaintiff resulting from the defendant's acts can be specifically ascertained, it is no defence that the plaintiff has also polluted the brook.

A land owner may collect the surfaue water of his land, and the water drawn from wells therein, into an artificial stream, and discharge this stream into a natural watercourse running through his land, provided that this is done in the reasonable use of his land, and that the volume of water is not increased beyond the natural capacity of the watercourse to discharge it, and the land of an adjoining owner is not thereby overflowed and materially injured.

Jackman v. Arlington Mills, 137 Mass. 277

the purposes of this Act, file in the office of the Registry of Deeds for the County where they are situated a description of the lands, ponds, or streams of water so taken, as certain as is required in common conveyance of lands and a statement of the purpose for which taken, which said description and statement shall be signed by the Mayor.

Now therefore know all men by these presents, that the said City of Boston by their Commissioners, Nathan Hale, James F. Baldwin and Thomas B. Curtis, duly appointed for this purpose, and by virtue of the power and authority in said Act given and in part execution of the same have taken and by these presents do take all the waters of said Long Pond so called and other brooks and streams whether permanent or temporary entering into the same, and of all the bays, coves and inlets thereof and of the outlet of the same and all the water-rights thereunto belonging or in any wise appertaining for the sole use and benefit of said City. And also for the use aforesaid the waters of Dug Pond so called and of the stream or streams entering into the same and also of the stream extending from said Dug Pond to said Long Pond -- all which waters and water-rights are situated in the towns of Natick, Wayland and Framingham in the County of Middlesex and Commonwealth of Massachusetts and covering an area exclusive of the streams flowing into the said Ponds of about seven hundred acres be the same more or less.

To hold the said waters and water-rights to the said City of Boston its successors and assigns to its and their sole

use and behoof forever agreeably to the provisions of said Act.

IN WITNESS WHEREOF, I Josiah Quincy, Jr., Mayor of the said City of Boston and the said Commissioners have prepared the foregoing description and statement of the waters and water-rights taken for the purposes aforesaid in conformity to the requirements of said Act to be filed in the office of the Registry of Deeds for said County of Middlesex this tenth day of August, A.D. 1846.

Josiah Quincy, Jr. Mayor.

Nathan Hale, :
Boston Water Commissioners.
James F. Baldwin, :

Thomas B. Curtis. :

Middlesex ss: August 19th, 1846. Received and recorded by Caleb Hayden, Register.

Taking of Sudbury River.

Whereas, by an Act of the Legislature of the Commonwealth of Massachusetts, passed the 8th day of April, A. D. 1872, entitled " an Act to authorize the City of Boston to obtain an additional supply of pure water," it is provided among other things, that

"The City of Boston is hereby authorized, by and through the agency of the Cochituate Water Board, to take, hold and convey to, into and through said city, all the water of Sudbury River, so called, said water to be taken at any point or points within the town of Framingham, or higher up on said river, and the water of Farm Pond, so called, in said town of Framingham, and the waters which may flow into and from said river and pond, and to take any water-rights in or upon said river or pond, in or above the town of Framingham, or connected therewith."

"And by section 5th of said Act, it is likewise provided that in regard to such taking, injury, interference or flowage, and the ascertainment and payment of all such damages, the said City of Boston, and all persons claiming damages, shall have all the rights, immunities and remedies, and be subject to all the duties, liabilties and regulations, which are provided in the one hundred and sixty-seventh chapter of the Acts of the year eighteen hundred and forty-six, and the three hundred and sixteenth chapter of the Acts of the year eighteen hundred and fifty.

" And, whereas, in said 167th chapter of the Acts of the year 1846, it is provided that the City of Boston shall, within sixty days from the time they shall take any lands or ponds, or streams of water, for the purposes of this Act, file in the office of the Registry of Deeds where they are situate, a description of the lands, ponds or streams of water so taken, as certain as is required in a common conveyance of lands, and a statement of the purpose for which taken; which said description and statement shall be signed by the said Mayor.

"And whereas, pursuant to the provisions of section 1st of Chapter 177, of the aforesaid Acts of 1872, it was ordered by the City Council of the City of Boston, that the Cochituate Water Board, as the agent of the City of Boston, be and it is hereby directed to take, hold, and convey to, into and through said city, all the water of Sudbury River, so called, said water to be taken at any point or points, within the town of Framingham, or higher up on said River, and the water of Farm Pond, so called, in said town of Framingham, and the waters which may flow into and from said river and pond, in and to take any water rights in or upon said river or pond, in or ~~about~~ above the town of Framingham, or connected therewith:

Said Cochituate Water Board is also hereby directed as the agent of this city, to take and ~~to~~ hold, by purchase or otherwise, in connection with said sources of supply, any lands and real estate necessary for increasing or preserving the purity of the water, or for laying, building, and main-

taining aqueducts, water courses, reservoirs, dams, buildings, machinery and other structures and appliances, with their accessories, for conducting, elevating, purifying, storing, discharging, disposing of, and distributing water; and also to take and hold any land (excepting any in the town of Framingham heretofore taken or purchased by any railroad company), on the margin of said sources of supply, not exceeding five rods in width, from the high water line of said River, storage reservoir or ponds, as far as may be necessary in the opinion of said Water Board, for the preservation and purity of the same, for the purpose of furnishing a supply of pure water for the City of Boston; the expense of the taking of the said waters and lands aforesaid to be charged to the appropriations already existing therefor.

"Provided, however, that, until the further order of the City Council, no land shall be taken for the construction of a conduit between Farm Pond and the Chestnut-Hill reservoir, and no money shall be expended therefor beyond the amount of the appropriations already made:-

Now, therefore, know all men by these presents, the City of Boston, by the Cochituate Water Board aforesaid, Thomas Gogin, Leonard R. Cutter, Charles R. McLean, L. Miles Standish, William G. Thacher, Edward A. White, and Edward P. Wilbur, duly appointed and constituted, and by the virtue of the power and authority in said Act given, and in part execution of the same, have taken, and by these presents do take, for the sole use and benefit of the said City of Boston, all the

water of Sudbury river, so called, at and above the dam built by the City of Boston, in 1872, five hundred feet, more or less, below the crossing of the said Sudbury River by the Boston, Clinton & Fitchburg Railroad, in the town of Framingham, in the County of Middlesex, and near the brook which is the outlet from Farm Pond into said River, and all the water in said dam to the source or sources of said river; also all the water in Farm Pond, so called, in said Town of Framingham, and all the water in the brook connecting Farm Pond with Sudbury River; also all the water in all the streams, brooks and rivulets, or water courses of any kind, whether natural or artificial, that may flow into or from said Farm Pond, and into or from said Sudbury River, at any point or points above said dam; subject to the restrictions set forth in Section 4 of Chap. 177 of the Laws of 1872, with reference to said water.

"To have and to hold the said waters to the said City of Boston, and its successors and assigns, to its and their sole use and behoof, agreeably to the provisions of the said Act of the year eighteen hundred and seventy-two.

In witness whereof, I, Samuel C. Cobb, Mayor of the said City of Boston, and the said Cochituate Water Board, have prepared the foregoing description of the water taken for the purposes aforesaid, in conformity to the requirements of the Acts aforesaid, to be filed in the office of the Registry of Deeds, for the said County of Middlesex, and have hereunto set

water of Sudbury River, so called, at and above the dam built by the City of Boston, in 1872, five hundred feet, more or less, below the crossing of the said Sudbury River by the Boston, Clinton & Fitchburg Railroad, in the town of Framingham, in the County of Middlesex, and near the brook which is the outlet from Farm Pond into said River, and all the water in said dam in the course or flowage of said river; also all the water in Farm Pond, so called, in said Town of Framingham, and all the water in the brook connecting Farm Pond with Sudbury River; also all the water in all the streams, brooks and rivulets, or water courses of any kind, whether natural or artificial, that may flow into, or from said Farm Pond, and into or from said Sudbury River, at any point or points above said dam; subject to the provisions set forth in Section 4 of Chap. 177 of the Laws of 1872, with amendments to said act.

To have and to hold the said waters to the said City of Boston, and its successors and assigns, to its and their sole use and behoof, agreeably to the provisions of the said Act of the year eighteen hundred and seventy-two.

In witness whereof, I, Samuel C. Cobb, Mayor of the said City of Boston, and the said Cochituate Water Board, have prepared the foregoing description of the water taken for the purposes aforesaid, in conformity to the requirements of the Acts aforesaid, to be filed in the office of the Registry of Deeds, for the said County of Middlesex, and have hereunto set

our hands and affixed the common seal of the City of Boston, being hereto duly authorized, the twenty-first day of January, in the year eighteen hundred and seventy-five.

Signed and
sealed in
presence of
James L. Hillard.

City of Boston
by
Samuel C. Cobb, Mayor.

Thomas Gogin, President .

Edward A. White.

Charles R. M'Lean.

William G. Thacher.

L. R. Cutter.

Edward P. Wilbur.

L. Miles Standish.